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SPACE VEHICLE SA-6 TELEMETRY SYSTEM

by TELEMETRY PERFORMANCE EVALUATION OFFICE, R-ASTR-ITP
Astrionics Laboratory

NASA

George C. Marshall Space Flight Center, Huntsville, Alabama

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Telemetry Performance Evaluation Office, R-ASTR-ITP

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ABSTRACT

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The performance evaluation of the complete telemetry systems (10 links) used for flight testing the SA-6 Saturn vehicle S-1-6 stage and S-IU-6 Instrument Unit is presented. The six telemetry links in the S-1-6 stage and the four telemetry links in the S-IU-6 Instrument Unit have been technically analyzed on an individual basis.

Statistical analyses were performed on much of the telemetry data, and the summarized results of these analyses are presented.

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TECHNICAL MEMORANDUM X-53284

SPACE VEHICLE SA-6 TELEMETRY SYSTEM

By

Telemetry Performance Evaluation Office, R-ASTR-ITP

INSTRUMENTATION AND COMMUNICATION DIVISION
ASTRIONICS LABORATORY
RESEARCH AND DEVELOPMENT OPERATIONS

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SPACE VEHICLE SA-6 TELEMETRY SYSTEM

SUMMARY

The complete telemetry systems, consisting of 10 telemetry links used for flight testing the SA-6 Saturn vehicles S-1-6 stage and S-IU-6 Instrument Unit, are analyzed for accuracy and adequacy. Each of the 10 telemetry links is analyzed on an individual basis and given separate coverage.

The overall performance of the telemetry systems used for flight testing the SA-6 Saturn vehicle was as anticipated.

I. INTRODUCTION

A. S-1-6 STAGE

Data transmission for flight testing the S-1-6 stage was accomplished by six telemetry links. Figure 1 is a block diagram of the S-1-6 stage telemetry system. The links comprising the S-1-6 stage telemetry system were as follows: two XO-6D systems, two XO-7 systems, one XO-10 system, and one XO-10B system.

The composite data handling capacity of the telemetry system was 56 continuous data channels and 673 commutated information handling channels.

B. S-IU-6 INSTRUMENT UNIT

Data transmission for flight testing the S-IU-6 Instrument Unit was accomplished by four telemetry links. Figure 2 is a block diagram of the S-IU-6 Instrument Unit telemetry system. The links comprising the S-IU-6 telemetry system were as follows: two XO-11C systems, one XO-7 system, and one pulse code modulation (PCM) system.

The composite data handling capacity of the S-IU-6 Instrument Unit telemetry system was 58 continuous data channels and 278 commutated information handling channels.

II. S-1-6 STAGE TELEMETRY LINKS

A. GENERAL

This section describes, illustrates, and evaluates the performance of each of the six telemetry links and the auxiliary equipment used on the S-1-6 stage. Table 1 lists the telemetry links used on the S-1-6 stage.

B. AIRBORNE TAPE RECORDER

An airborne tape recorder, located in canister F1, instrument compartment 13 of the S-1-6 stage, recorded the output of the mixer/amplifier of telemetry link F2. During the playback mode, the transmitter was switched from the mixer/amplifier to the recorder. The purpose of the recorder was to record data during the periods when RF dropout normally occurred because of flame attenuation, retro and ullage rocket firing, look angle, etc.

The airborne tape recorder was in the record mode from 40.2 seconds* to 175.6 seconds. Recorder transfer from record mode to playback mode was initiated at 175.6 seconds and required an elapsed time of 0.95 seconds. The recorder began playback of data at 176.5 seconds and completed data playback at 311.75 seconds. At completion of recorder playback, real-time modulation was not reapplied, and only the unmodulated RF carrier remained active.

The airborne tape recorder operated satisfactorily, and data contained in the playback record were free of the effects of retrorocket flame attenuation.

C. COMMUTATORS

A type B commutator is a 30-channel by 120 sample-per-second time division multiplexer. Twenty-seven of the channels are data channels; the remaining three are used for reference and PAM frame identification. Twenty-three of the channels may be subcommutated for 10 channels each at 12 sample-per-second sampling rate.

A type D vibration commutator is a 4-channel solid-state commutator that shares 4 channels of vibration data and samples each channel once each 12 seconds for a 3-second duration.

A type E vibration commutator is a 2-channel solid-state multiplexer that shares 2 channels of vibration data and samples each channel once each 12 seconds for a 6-second duration.

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*Times given are in seconds after liftoff.

TABLE 1. S-1-6 STAGE TELEMETRY LINKS

LINK	SYSTEM	FREQ. (MHz)	DATA HANDLING CAPACITY (NO. CHANNELS)	AUXILIARY COMPONENTS	CHANNEL MODIFICATIONS
F1 (Fig. 3)	XO-6D	242.0	Commutated--270 Continuous--13	None	Channels 11 and 12 were modified to accept 7.35 (±7.5%) kHz and 10.5 (±7.5%) kHz, respectively, by replacing voltage-controlled oscillators with respective vibrotron filters.
F2 (Fig. 4)	XO-6D	248.6	Commutated--270 Continuous--13	Airborne tape recorder	Same as link F1
F3 (Fig. 5)	XO-10B	246.3	Commutated--54 Continuous--13	Type F commutator was used on channel X	Same as link F1
F4 (Fig. 6)	XO-10	243.8	Commutated--27 Continuous--13	Type G commutator was used on channel X	Same as link F1
S1 (Fig. 7)	XO-7	252.4	Commutated--16 Continuous--11	Type D vibration commutators were used on Channels 11, 12, 13, and 14.	None
S2 (Fig. 7)	SS/FM	256.2	Commutated--36	Type D vibration commutators were used on Channels 9, 10, and 15. Type E vibration commutators were used on Channels 1 thru 8 and 11 thru 14.	None

A type F commutator is a 30-channel by 120 sample-per-second solid-state commutator capable of handling two groups of inputs each consisting of 27 data channels. Each group was sampled once each 6 seconds for a 3-second duration. Presampling filters with dc to 24 Hz response were used in front of all inputs to this commutator.

A type G commutator is a 30-channel by 120 sample-per-second solid-state commutator capable of handling 27 data channels. Presampling filters with dc to 25 Hz response were used in front of all inputs to this commutator.

D. CALIBRATION

Telemeters F1 and F2 type B commutator channels received preflight and inflight calibration from the calibrator located within the respective commutator assemblies. Telemeters S1 and S2 received preflight calibration from the swept-frequency calibrator located in the ground support equipment rack under the launching pad. The central calibrator, located in the S-1-6 stage, supplied preflight and inflight calibration to telemeters F3, F4, and the continuous data channels of telemeters F1 and F2. All preflight and inflight calibrations were normal and satisfactory.

E. RF POWER TESTS

Table 2 shows the results of RF power tests performed on the S-1-6 stage telemetry systems at Cape Kennedy by the Telemetry Field Section. The RF power was measured at the input and output of the various multicouplers.

F. OVERALL PERFORMANCE

The performance of all S-1-6 stage telemetry links was satisfactory. Transmitted RF power was sufficient to produce good data at all tracking stations. No RF-signal dropout problems were encountered other than those caused by the retrorocket exhaust plume and normally expected and provided for at staging.

TABLE 2. SA-6 TELEMETRY SYSTEM RF POWER TEST RESULTS

Telemetry Link	Frequency (MHz)	Stage	Antenna Multicoupler		Multicoupler Power Loss (db)
			Input	Output	
F1	241.5	S-1-6	37.0	27.0	1.4
F2	248.6	S-1-6	30.0	21.5	1.4
F3	246.3	S-1-6	32.5	27.0	0.8
F4	243.8	S-1-6	30.0	25.0	0.8
S1	252.4	S-1-6	32.5	26.0	1.0
S2	256.2	S-1-6	34.0	28.0	0.8
F5	249.9	S-IU-6	25.0	20.0	1.0
F6	240.2	S-IU-6	33.0	27.0	1.8
P1	253.8	S-IU-6	15.0	11.8	1.0
S3	259.7	S-IU-6	34.0	23.0	1.7

Average output power (excluding link P1) = 24.9 watts
Standard deviation = ±2.7 watts

III. S-IU-6 INSTRUMENT UNIT TELEMETRY LINKS

A. GENERAL

This section describes, illustrates, and evaluates the performance of each of the four telemetry links and the auxiliary equipment used on the S-IU-6. Table 3 lists the telemetry links used on the S-IU-6.

B. AIRBORNE TAPE RECORDER

The airborne tape recorder located in the S-IU-6 Instrument Unit recorded the mixer/amplifier outputs of links F5 and F6. During the playback mode, the transmitter was switched from the mixer/amplifier to the recorder. The purpose of the recorder was to record data during the period when RF dropout occurred because of flame attenuation and retro and ullage rocket firing.

The airborne tape recorder was in the record mode from 141. 6 seconds to 170. 8 seconds. Recorder transfer from record mode to playback mode was initiated at 659. 5 seconds and required an elapsed time of 1. 9 seconds. The recorder began playback of data at 661. 4 seconds and completed data playback at 688.7 seconds.

Operation of the airborne tape recorder was good, and data contained in the playback record are usable. Some effects of wow and flutter can be seen in the data from the tape recorder; however, by using a 120-kHz tape speed compensation system, it is believed that the wow and flutter effects can be removed from the data.

C. COMMUTATORS

Type D and E vibration commutators were used on the S-IU-6 and are the same type used on the S-1-6 stage and described in Section II.

D. CALIBRATION

Telemeter P1 received preflight and inflight calibrations from the calibrator located within the commutator assembly. Telemeter S3 received preflight calibration from the swept-frequency calibrator located in the ground support equipment rack under the launching pad. The central calibrator located in the S-IU-6 Instrument Unit supplied preflight and inflight calibration to telemeters F5 and F6.

TABLE 3. S-IU-6 INSTRUMENT UNIT TELEMETRY LINKS

LINK	SYSTEM	FREQ. (MHz)	DATA HANDLING CAPACITY (NO. CHANNELS)	AUXILIARY COMPONENTS	CHANNEL MODIFICATIONS
F5 (Fig. 8)	XO-11C	249.9	Continuous--27	Airborne tape recorder	Channels 14 and 17 were modified for an input range of ±2.5 volts to accommodate the ac input signal from the triple-FM subcarriers.
F6 (Fig. 9)	XO-11C	240.2	Commutated--4 Continuous--27	Type D vibration commutator was used on Channel 11. Airborne tape recorder	Same as link F5
P1 (Fig. 10)	PCM	253.8	Commutated--270	None	None
S3 (Fig. 7)	XO-7	259.7	Commutated--42 Continuous--4	Type D vibration commutators were used on Channels 5, 6, 7, 8, 10, 11, 12, and 13. Type E vibration commutators were used on Channels 1, 2, 3, 4, and 15.	None

E. RF POWER TESTS

Table 2 shows the results of RF power tests performed on the S-IU-6 telemetry systems at Cape Kennedy by the Telemetry Field Section. The RF power was measured at the input and output of the various multicouplers.

F. OVERALL PERFORMANCE

The performance of all S-IU-6 telemetry links was satisfactory except as noted below. Transmitted RF power was sufficient to produce good data at all tracking stations. No RF-signal dropout problems were encountered.

The PCM system (link P1) functioned satisfactorily until approximately 55 minutes. It was expected to have functioned until approximately 180 minutes, but was lost earlier because of a network wiring error. Insertion of a digital horizon sensor, radar altimeter, and guidance computer data into the PCM system worked very satisfactorily. Bit error rates of this digital transmission system are very low when received RF signals are at usable levels.

The S-IU-6 Instrument Unit contained two batteries that supplied power to the telemetry packages, the D10 battery (short life) and the D20 battery (long life). The network wiring contained relays which, when energized, connected the various telemetry packages to their respective battery. The PCM system was connected erroneously through relay K47 to the D20 battery. Relay K47 was energized by the D10 battery. Depletion of D10 battery power caused relay K47 to deenergize, disconnecting D20 battery power to the PCM system.

IV. FM/FM SYSTEMS EVALUATION

A. PRECISION

Precision figures were calculated using available preflight calibration data. All precision figures are based on a 3-sigma (99 percent) confidence level.

Shown below are precision figures calculated for each individual FM/FM system. Values are in percent of calibration level range.

F1 (XO-6D)	F2 (XO-6D)	F3 (XO-10B)	F4 (XO-10)	F5 (XO-11C)	F6 (XO-11C)
1.005%	1.218%	0.864%	0.906%	1.227%	0.810%

Precision figures were calculated for identical systems and are shown below. Values are in percent of calibration level range.

XO-6D (F1, F2)	XO-11C (F5, F6)
1.101%	1.053%

Using the precision figures obtained from each of the telemetry systems, an estimate of the overall precision was calculated for the SA-6 continuous FM/FM channels. The estimated overall precision was found to be ±1.023 percent based on a 3-sigma (99 percent) confidence level.

B. STATISTICAL TESTS

Available preflight calibration data from each of the six FM/FM telemeters were statistically analyzed to determine if the variability was constant. Each telemeter was analyzed separately and similar systems were compared. Two types of statistical tests were used for this analysis. Bartlett's test [1] was used for tests within telemeters and the F-ratio test [1] was used for tests between telemeters. All tests are based on a 2-sigma (95 percent) confidence level.

Tables 1 through 6 in the Appendix show the data and telemeter channels used for the tests.

1. Tests on Each Telemeter. Two tests were performed on the channel variances for each telemeter to determine if the variances were significantly different. Test number one analyzed the variances within the same calibration

level between channels, while test number two analyzed the variances for each channel including all calibration levels. The results of these tests are summarized below.

Test number one (Bartlett's test): Significant differences were found between channels for the calibration levels listed below.

F1 - 0, 50, and 100 percent levels

F2 - 50 and 100 percent levels

F3 - 75 percent level

F4 - 50 and 100 percent levels

F5 - 0, 25, 50, and 75 percent levels

F6 - 50 percent level

Test number two (Bartlett's test): Significant differences were found between calibration levels for the channels listed below.

F1 - Channels 3 and 14

F2 - Channels 2 and 3

F3 - None

F4 - Channel 3

F5 - Channel 3

F6 - None

2. Comparison of Similar Telemeters. An overall variance was computed for each telemeter, including all calibration levels and channels. The overall variances for similar telemeters were compared, using the F-ratio test, to determine if the variances were significantly different. The results were as follows:

F1 and F2 (XO-6D's) - No significant differences

F5 and F6 (XO-11C's) - No significant differences

V. PCM SYSTEM ANALYSIS

A. PRECISION

Precision figures were calculated using the data from the six inflight calibrations. All precision figures are based on a 2-sigma (95 percent) confidence level.

Table 4 shows precision figures in percent of calibration level range for each calibration. Also shown is a combined precision for each of the five calibration levels calculated by combining all six calibrations.

An overall precision was calculated by combining all calibrations and calibration levels. The estimated overall precision was found to be ± 0.128 percent based on a 2-sigma (95 percent) confidence level.

Table 5 shows means and standard deviations in percent of range for PCM flight test calibration data.

B. STATISTICAL TESTS

Statistical tests were performed on the variances associated with each of the calibration levels to determine if the variances were homogeneous. Bartlett's test [1] and the F-ratio test [1] were used. All tests are based on a 2-sigma (95 percent) confidence level.

1. Each Calibration Between Calibration Levels. Bartlett's test was used on each separate calibration to determine if the calibration level variances were homogeneous. The results of the test show that the calibration level variances were not homogeneous within a calibration. The following table shows the calculated M/C values.

Calibration	1	2	3	4	5	6
M/C Ratio	39.045	48.620	122.803	220.500	47.034	54.410

Degrees of freedom = 4

Chi-squared table values = 9.49

To determine if any two or more of the variances were homogeneous, an F-ratio test was used. The results are as follows; no consistent pattern of homogeneity was found to exist.

TABLE 4. PRECISION OF SA-6 PCM/FM CALIBRATION BY LEVEL BASED ON A 2-SIGMA (95 PERCENT) CONFIDENCE LEVEL

Calibration Levels	Calibration Number *						Combined Levels*
	1	2	3	4	5	6	
0%	±0.080	±0.090	±0.074	±0.036	±0.042	±0.034	±0.062
25%	±0.124	±0.084	±0.062	±0.084	±0.056	±0.068	±0.082
50%	±0.158	±0.156	±0.236	±0.214	±0.072	±0.700	±0.162
75%	±0.106	±0.176	±0.104	±0.074	±0.088	±0.096	±0.112
100%	±0.076	±0.168	±0.154	±0.212	±0.098	±0.070	±0.140

* All figures shown in percent of calibration level range.

TABLE 5. SA-6 PCM FLIGHT TEST CALIBRATION DATA

Inflight Calibration No.	Calibration Levels *										Total Dev*	% Change Based on First Calibration	
	0%		25%		50%		75%		100%				
	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.	Mean	Std. Dev.		Change in 0% Means Based on First Calibration Means	Range Change in % Based on First Calibration Range
1	0	0.040	25.056	0.062	49.997	0.079	75.046	0.053	100	0.038	0.057	------	------
2	0	0.045	25.063	0.042	49.999	0.078	75.052	0.085	100	0.084	0.069	-.007%	+.008%
3	0	0.037	25.000	0.031	50.002	0.118	75.058	0.052	100	0.077	0.071	0	-.001%
4	0	0.018	25.050	0.042	49.999	0.107	75.050	0.037	100	0.106	0.072	+.015%	-.024%
5	0	0.021	25.050	0.028	50.010	0.036	75.040	0.044	100	0.049	0.036	+.015%	-.024%
6	0	0.017	25.050	0.034	50.010	0.035	75.050	0.048	100	0.035	0.035	+.016%	-.020%

* All figures shown in percent of range.

	CALIBRATION LEVEL	VARIANCE (percent of range)	
Calibration 1	50%	0.0062	
	25%	0.0038	homogeneous
	75%	0.0028	
	0%	0.0016	homogeneous
	100%	0.0014	
Calibration 2	75%	0.0072	
	100%	0.0071	homogeneous
	50%	0.0061	
	0%	0.0020	homogeneous
	25%	0.0018	
Calibration 3	0%	0.0014	
	25%	0.0010	
	50%	0.0139	
	75%	0.0027	
	100%	0.0059	
Calibration 4	50%	0.0115	homogeneous
	100%	0.0112	
	25%	0.0018	homogeneous
	75%	0.0014	
	0%	0.0003	

Calibration 5	100%	0.00240	- homogeneous
	75%	0.00194	
	50%	0.00130	
	25%	0.00078	
	0%	0.00044	
Calibration 6	75%	0.002304	
	50%	0.001225	- homogeneous
	100%	0.001225	
	25%	0.001156	
	0%	0.000289	

2. Each Calibration Level Including All Calibrations. Bartlett's test was used on each separate calibration level to determine if the level variances were homogeneous between calibrations. The results of the test indicated that the level variances are not homogeneous between calibrations. The following table shows the calculated M/C values.

Calibration Level	0%	25%	50%	75%	100%
M/C Ratio	96.924	44.476	132.258	43.829	103.066

Degrees of freedom = 4

Chi-squared table value = 11.1

VI. AIRBORNE TAPE RECORDER

A. GENERAL

The purpose of this study is to determine the effects of the airborne tape recorder on the telemetered data. Because the recording period of the airborne tape recorder for S-1-5 (F2) and S-1-6 (F2) flight tests contained an inflight calibration, the resulting real-time and playback data from both flights were used. The calibration data were obtained from telemeter F2, IRIG channels 5, 10, and 14 of S-1-5 and S-1-6 flight test recordings.

Two methods were used to determine whether the playback calibration data were different from the real-time data. The standard deviations of the calibrations within each flight were compared to determine if there was a difference in noise level. The means (averages) of the calibration levels within each flight were compared to determine if a shift (bias) in magnitude occurred.

B. NOISE ANALYSIS

1. Plot of Standard Deviations. Noise can be defined as the variability of output with a given input; therefore, a graphical plot of the standard deviations of real-time and playback data will give an indication of the relative noise levels. Because the calibration level range varies from channel to channel, the standard deviations were converted to a percentage of full scale readings before plotting. The standard deviations were plotted for all calibration levels of a channel for real-time and playback data and are shown in Figures 11 through 16. The plots indicate that the real-time data had consistently less noise than the playback data. Note that for practical purposes the differences were negligible in percentage of range.

2. F-Ratio Test [1]. To determine the statistical significance in the differences between noise levels for real-time and recorded data, the F-ratio test was applied to the standard deviations. The results of these computations are summarized in Table 6 and presented in detail in Tables 7 and 8 in the Appendix. The noise of the playback is significantly greater (statistically) than that of the real-time data, but negligible percentage-wise.

3. Estimate of Noise Added by Airborne Playback to Real-Time Data. The real-time data were compared with the playback data to estimate noise added by airborne playback. This was done by pairing standard deviations, comparing them, and computing the difference and percent increase. The results of these computations are summarized in Table 7 and presented in detail

TABLE 6. SUMMARY OF VARIANCE RATIOS SIGNIFICANCE

Vehicle	Channel	0%	25%	50%	57%	100%
SA-5	5	*	*		*	*
SA-5	10	*	*	*	*	*
SA-5	14	*	*	*	*	*
SA-6	5	*	*		*	
SA-6	10	*	*	*		*
SA-6	14			*	*	*

*Playback greater at 0.01 level of significance

TABLE 7. SUMMARY OF DIFFERENCE OF NOISE OF REAL-TIME DATA VERSUS PLAYBACK DATA LINK F2

Vehicle	Level	Av. Real-Time Noise Level	Av. Tape Noise Level	Av. Noise Diff.	Av. % Increase
SA-5	0	.410	.638	.227	59.506
SA-6	0	.362	.469	.107	33.466
SA-5	25	.354	.575	.221	94.050
SA-6	25	.384	.436	.051	35.780
SA-5	50	.377	.570	.195	51.360
SA-6	50	.282	.401	.118	43.386
SA-5	75	.448	.780	.332	83.376
SA-6	75	.402	.453	.050	8.078
SA-5	100	.400	.683	.283	85.450
SA-6	100	.462	.606	.144	39.356

Entire Study:

Av. Noise Difference = .173
Av. % Increase = 53.381
SA-5 Av. Noise Difference = .252
SA-5 Av. % Increase = 74.749
SA-6 Av. Noise Difference = .094
SA-6 Av. % Increase = 32.014

in Table 9 in the Appendix. Note that the data from the playback are approximately 53.381 percent more noisy than real-time data. The average count difference between playback noise and real-time noise is 0.173 count. These two computations indicate that the playback is significantly more noisy than real-time, but that the increase in noise is very slight in percentage of range. The use of tape speed compensation in the data reduction will improve the noise expectations on both the real-time and playback data. However, for the purpose of this operation, it is not desirable to add the optimization effect of tape speed compensation.

C. MEAN ANALYSIS

1. Differences Between Inflight Real-Time Means and Playback Means. It is desirable to determine what differences, if any, existed between real-time and playback calibration level means. A shift in means of a significant magnitude between real-time and playback data would result in erroneous engineering values if a calibration was not present during the airborne recording. If significant shifts do exist, an inflight calibration during the airborne recording would be a means of correction.

2. Mean Difference Test [1]. To determine the statistical significance of the differences in means between airborne playback and real-time data, mean difference tests were applied to the means using a 99 percent confidence level. The results of these computations are summarized in Tables 8 and 9. The following tabulation presents the playback means in a number of cases that are smaller, larger, or show no significant difference.

Vehicle	No significant difference	Playback significantly larger	Playback significantly smaller
SA-5	6 cases (40.0%)	3 cases (20.0%)	6 cases (40.0%)
SA-6	2 cases (13.3%)	2 cases (13.3%)	11 cases (73.4%)
SA-5 and SA-6 Combined	8 cases (26.7%)	5 cases (16.7%)	17 cases (56.6%)

In general, the majority of the playback means are significantly smaller than the real-time means.

TABLE 8. SUMMARY OF SA-5 MEAN DIFFERENCE TESTS

Channel	Level (%)	t Value	Significance
5	0	-7.80 *	**
	25	-1.12 *	
	50	-2.95 *	**
	75	-0.064*	
	100	1.43	
10	0	1.64	
	25	8.64	**
	50	1.88	
	75	-1.10 *	
	100	-7.32 *	**
14	0	7.09	**
	25	6.09	**
	50	5.34	**
	75	3.66	**
	100	3.63	**

* The negative sign designates that the playback mean was greater than the real-time mean.

** Playback mean was significantly different from real-time mean at a 99 percent confidence level; $t_{0.99} = 2.326$ with n (degrees of freedom) > 120.

TABLE 9. SUMMARY OF SA-6 MEAN DIFFERENCE TESTS

Channel	Level (%)	t Value	Significance
5	0	-1.94 *	
	25	14.90	**
	50	16.10	**
	75	4.41	**
	100	-5.99 *	**
10	0	22.40	**
	25	43.10	**
	50	25.80	**
	75	13.80	**
	100	-4.17 *	**
14	0	8.78	**
	25	11.90	**
	50	10.80	**
	75	6.14	**
	100	1.32	**

* The negative sign designates that the playback mean was greater than the real-time mean.

** Playback mean was significantly different from real-time mean at 99 percent confidence level; $t_{0.99} = 2.326$ with n (degrees of freedom) > 120.

3. Estimate of Decrease in Means Caused by Airborne Playback. To estimate the decrease in magnitude of real-time means, the difference between the real-time and playback data was calculated. Using the real-time means and the real-time calibration ranges as a reference, percent decreases were calculated. These computations are summarized in Table 10 and shown in detail in Table 10 in the Appendix. Note that the playback means decreased by only 2.930 counts. The average percent difference in the airborne playback means and real-time means was 0.327 percent. These two figures indicate that the difference between the real-time and airborne playback means was statistically significant, but that the actual difference in means is very slight with comparison to full scale percentages. The use of tape speed compensation in data reduction would have decreased the difference in the real-time and playback comparison, but the purpose of this operation was to determine the real differences before attempting optimization.

TABLE 10. SUMMARY OF DIFFERENCE OF MEANS

Vehicle	Level (%)	Av. Airborne Playback Means	Av. Real Time Means	Av. Decrease	Percent Decrease
SA-5	0	60.552	61.815	1.264	0.146
SA-6	0	68.969	73.481	4.513	0.503
SA-5	25	290.797	293.687	2.890	0.323
SA-6	25	293.873	302.580	8.707	0.971
SA-5	50	517.250	519.081	1.831	0.206
SA-6	50	519.229	525.700	6.471	0.721
SA-5	75	742.281	743.339	1.058	0.119
SA-6	75	744.068	747.974	3.907	0.436
SA-5	100	968.422	906.607	0.110	0.016
SA-6	100	971.721	970.341	-1.381	-0.459

Entire Study:

Av. Mean Decrease = 2.930 counts
Av. % Mean Decrease = 0.327
SA-5 Av. Mean Decrease = 1.416 counts
SA-5 % Mean Decrease = 0.160
SA-6 Av. Mean Decrease = 4.443 counts
SA-6 % Mean Decrease = 0.496

VII. VEHICLE TELEMETRY FLIGHT ENVIRONMENT DATA

Flight environment parameters in the form of pressure, temperature, and vibration were measured in the S-1-6 stage and S-IU-6 Instrument Unit stage areas containing the airborne telemetry systems.

A. S-1-6 STAGE

The airborne telemetry equipment, used for acquisition and transmission of flight data from the S-1-6 stage, was located in canister F1, instrument compartment 13. Structural vibration components in three major axes were measured in this canister at a representative location throughout the flight period. The results of these measurements give an insight into the actual flight vibration environment for the telemetry systems. Figure 17 shows the locations of the various telemetry assemblies and the vibration monitor points in canister F1, instrument compartment 13. Figures 18 and 19 show the acquired vibration data reduced to significant engineering values.

B. S-IU-6 INSTRUMENT UNIT

The airborne telemetry equipment used for acquisition and transmission of the S-IU-6 Instrument Unit flight data was located in tube 3 of the Instrument Unit. Environmental measurements made in this area were: vibration in three major axes, air temperature, and air pressure. The results of these measurements give some insight into the actual flight environment for the telemetry systems within the S-IU-6 Instrument Unit. Figures 20, 21, and 22 show the locations of various telemetry assemblies and environmental monitor points in the Instrument Unit. Figures 23, 24, and 25 show the environmental data reduced to significant engineering values.

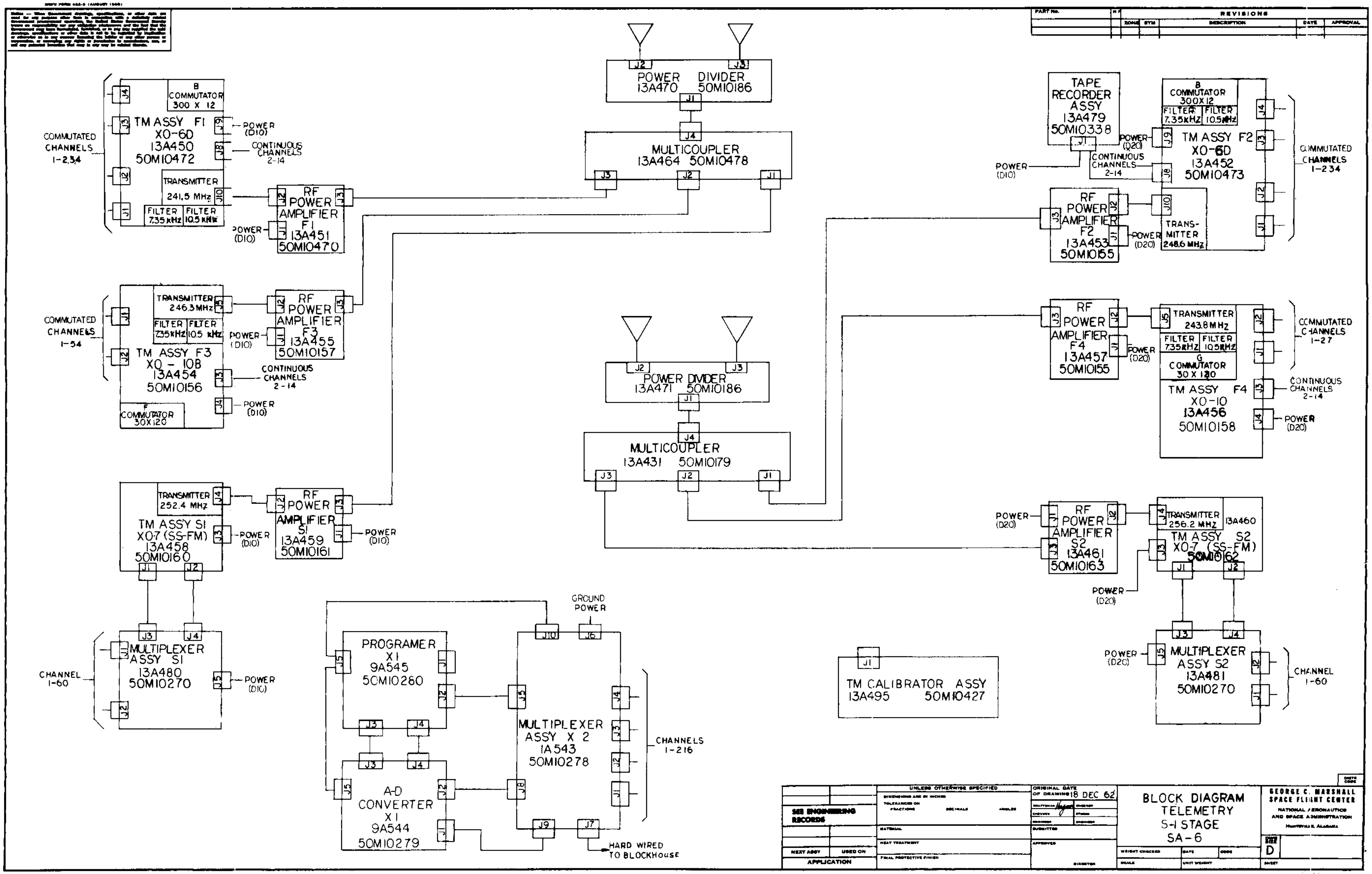


FIGURE 1. BLOCK DIAGRAM OF S-1-6 STAGE TELEMETRY SYSTEM

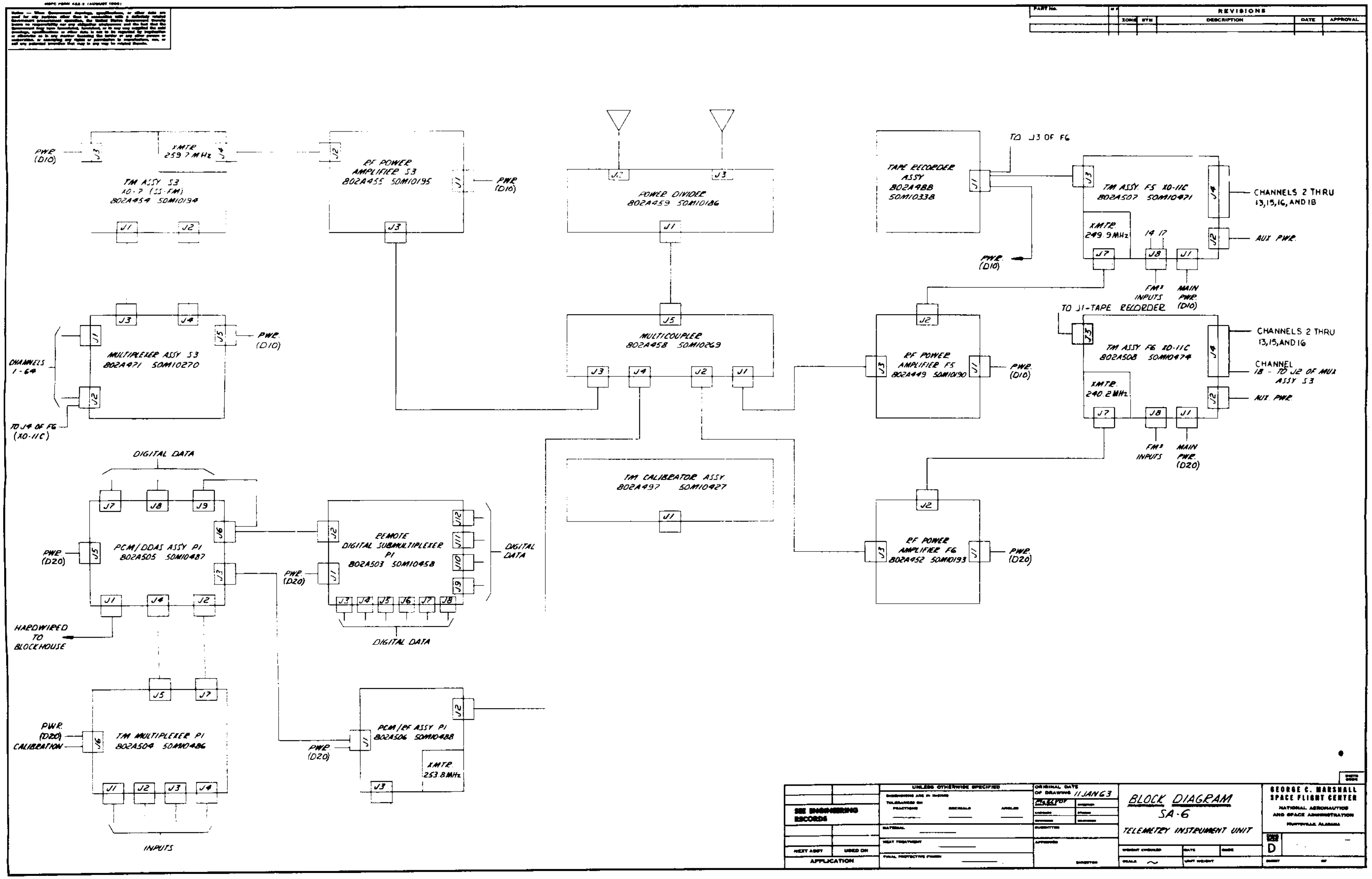


FIGURE 2. BLOCK DIAGRAM OF S-IU-6 INSTRUMENT UNIT TELEMETRY SYSTEM

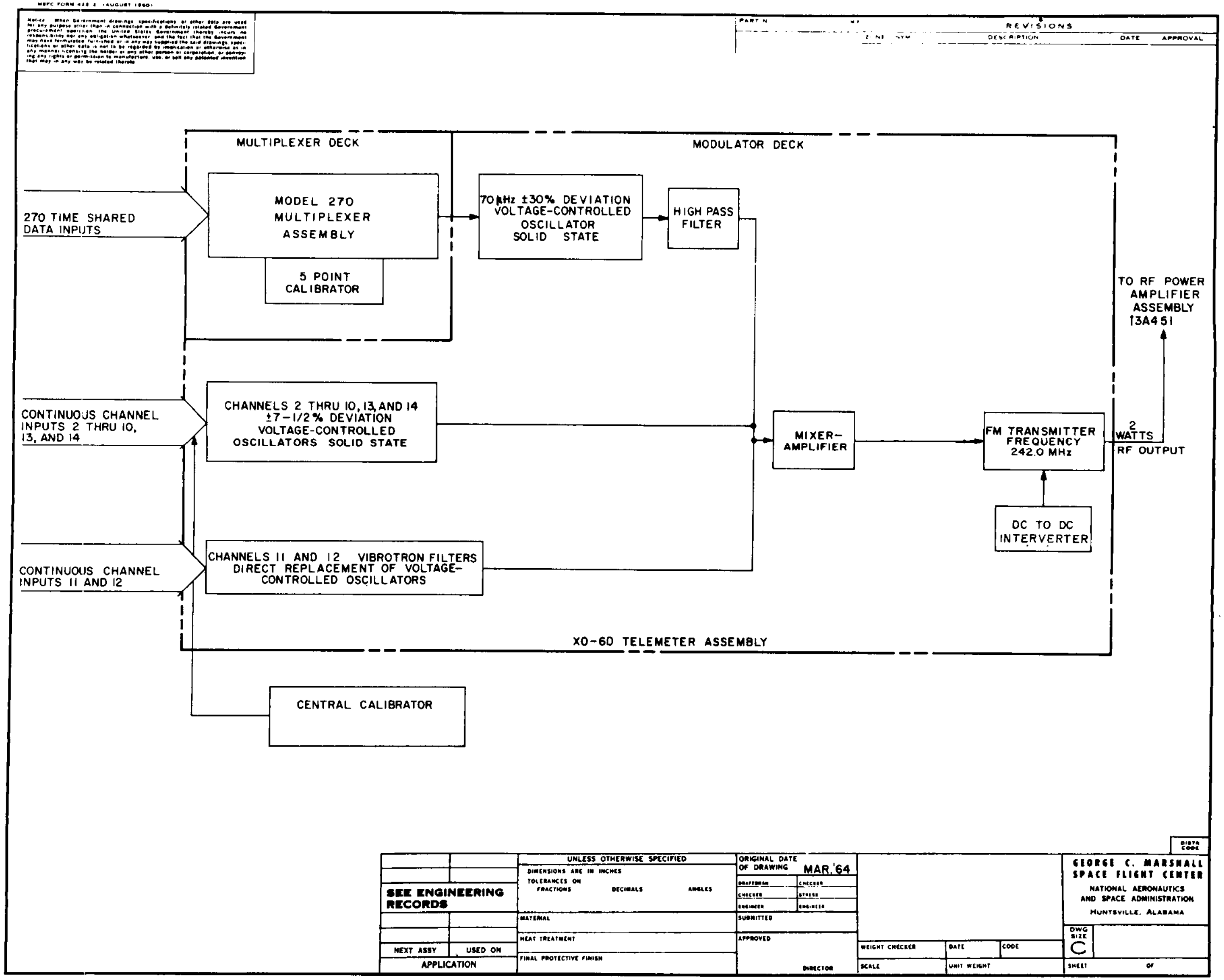


FIGURE 3. S-1-6 TELEMETER LINK F1

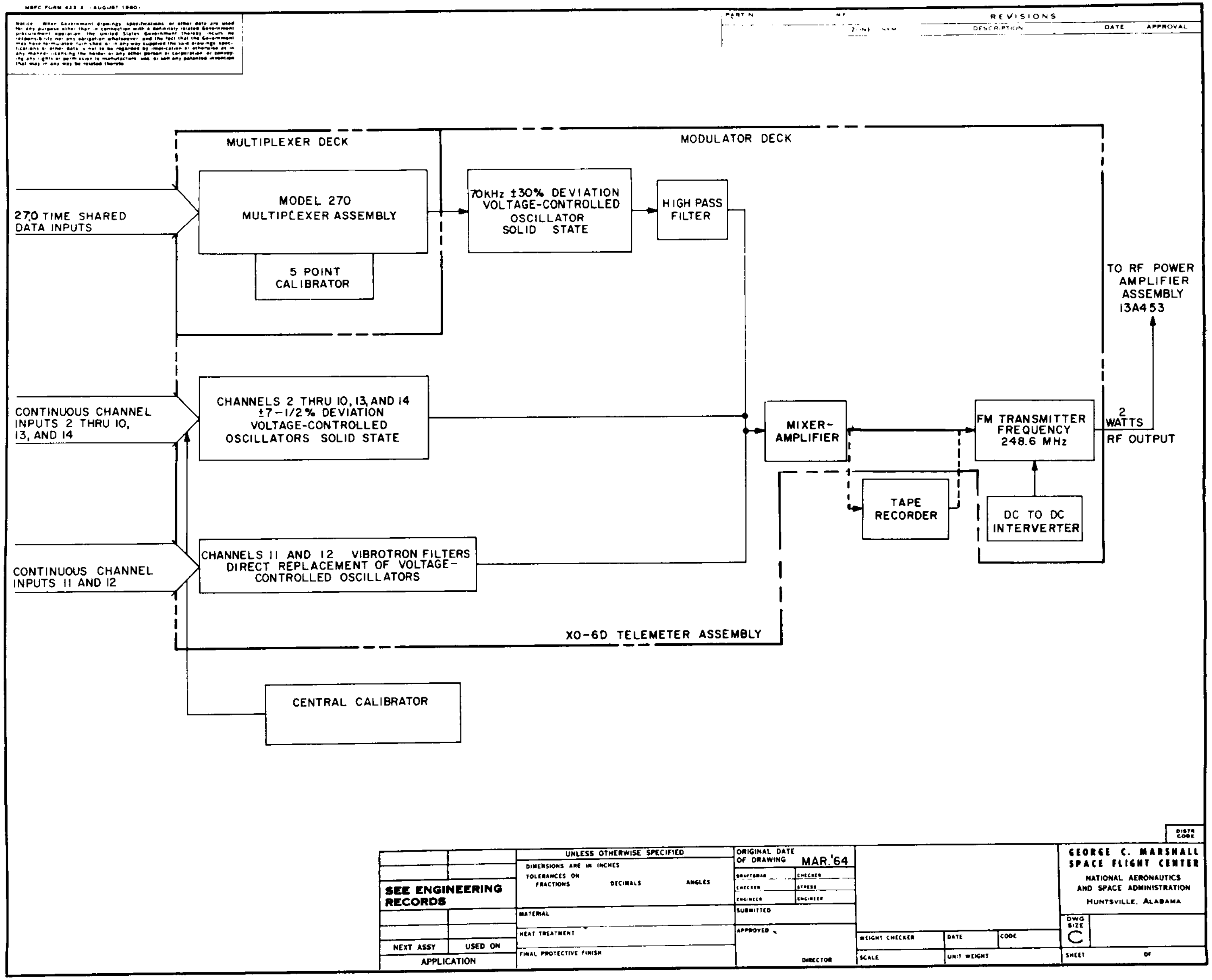


FIGURE 4. S-1-6 TELEMETER LINK F2

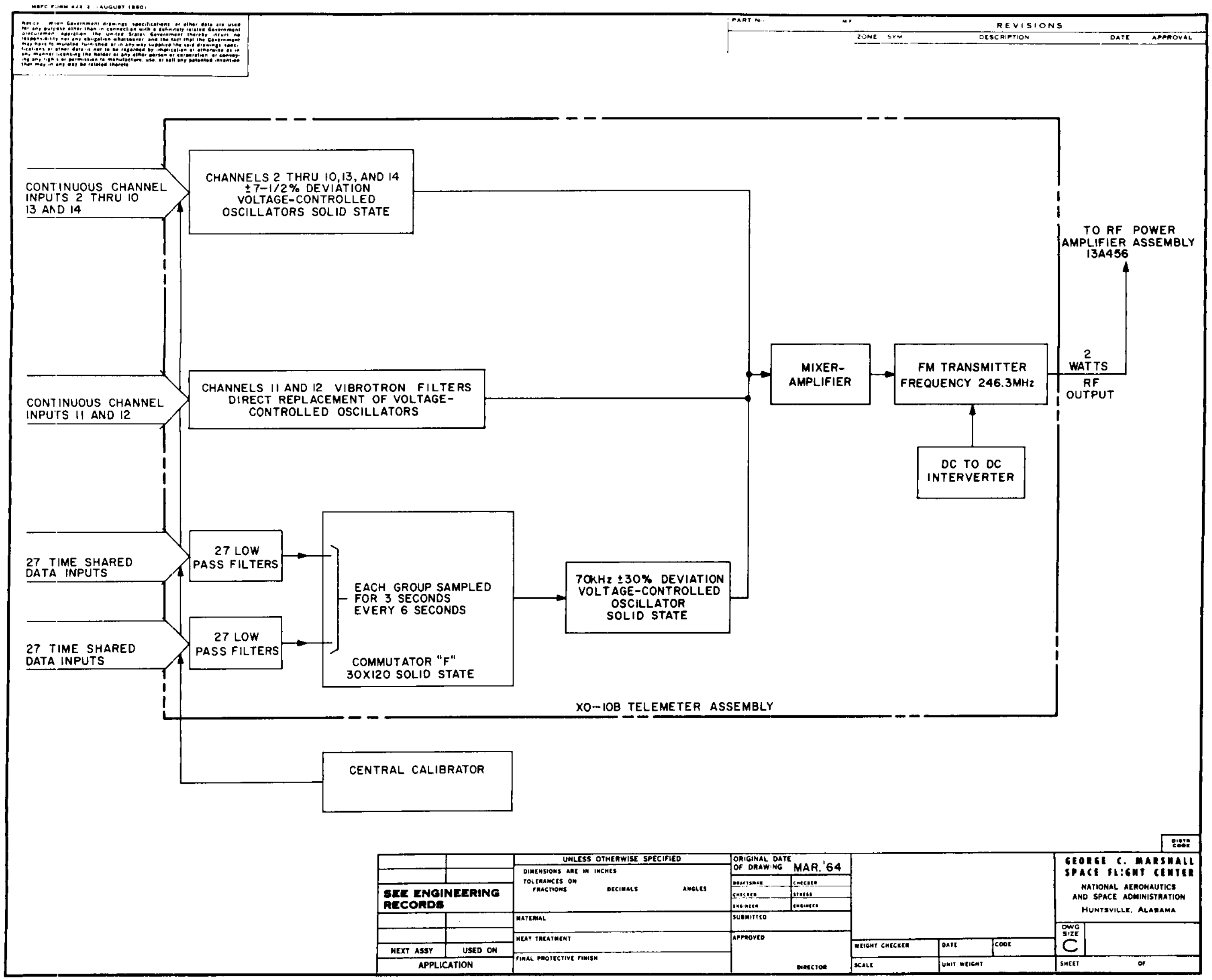


FIGURE 5. S-1-6 TELEMETER LINK F3

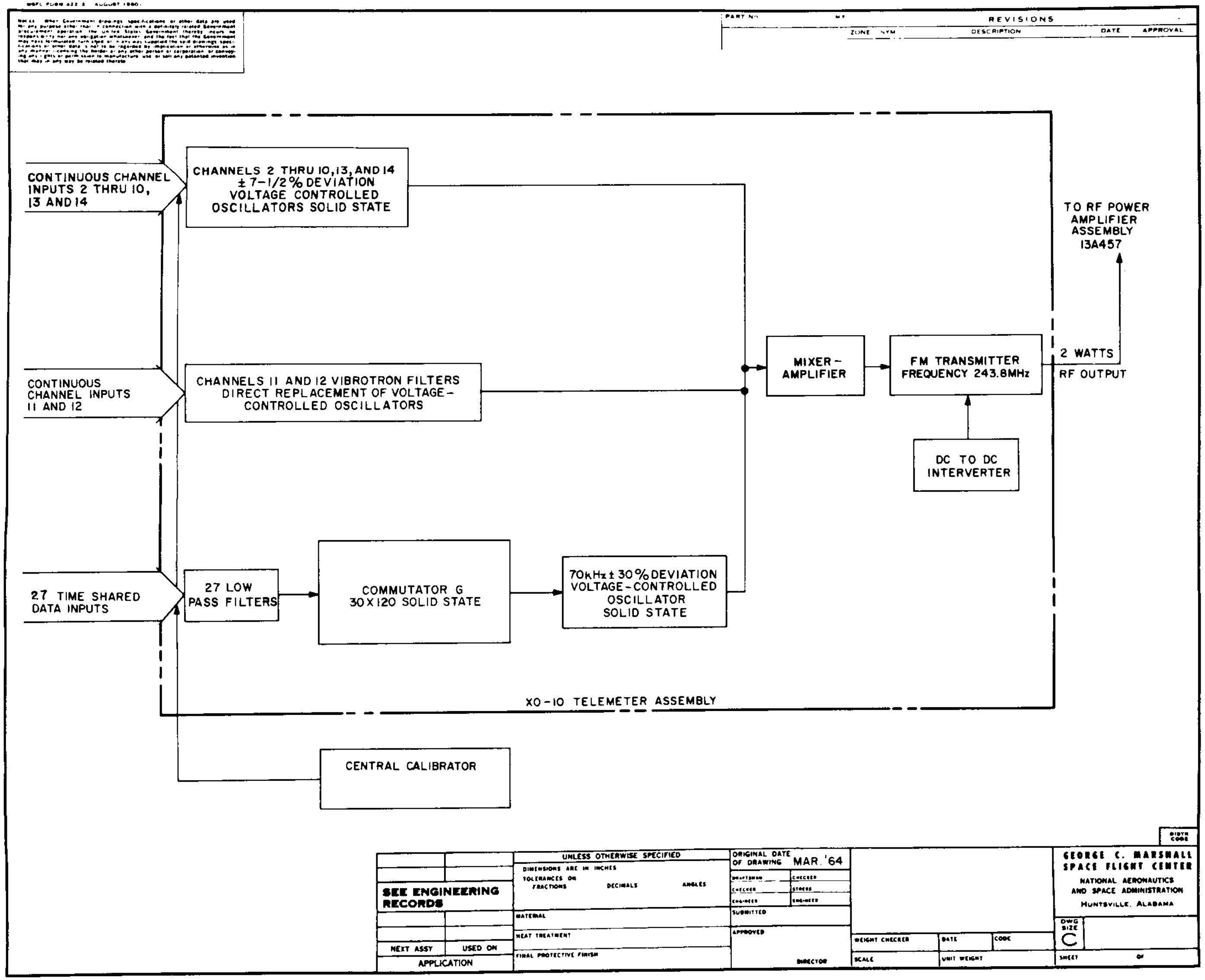
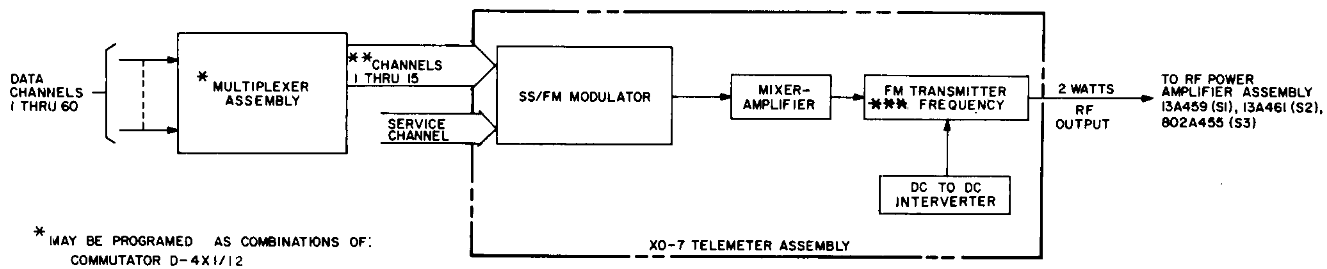


FIGURE 6. S-1-6 TELEMETER LINK F4



* MAY BE PROGRAMED AS COMBINATIONS OF:
COMMUTATOR D-4X1/12
COMMUTATOR E-2X1/12
CONTINUOUS CHANNELS

** MULTIPLEXER PROGRAM

SS/FM CHANNEL	TELEMETER S1 CONTINUOUS	S1 COMMUTATED	S2 CONTINUOUS	S2 COMMUTATED	S3 CONTINUOUS	S3 COMMUTATED
1	1			2		2
2	1			2		2
3	1			2		2
4	1			2		2
5	1			2		4
6	1			2		4
7	1			2		4
8	1			2		4
9	1			4	1	
10	1			4		4
11		4		2		4
12		4		2		4
13		4		2		4
14		4		2	1	
15	1			4		2

*** FREQUENCIES: S1-252.4MHz
S2-256.2MHz
S3-259.7MHz

SEE ENGINEERING RECORDS

ORIGINAL DATE OF DRAWING MAR. '64

GEORGE C. MARSHALL SPACE FLIGHT CENTER
NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
HUNTSVILLE, ALABAMA

DWG SIZE C

FIGURE 7. SA-6 TELEMETER LINKS S1, S2, AND S3

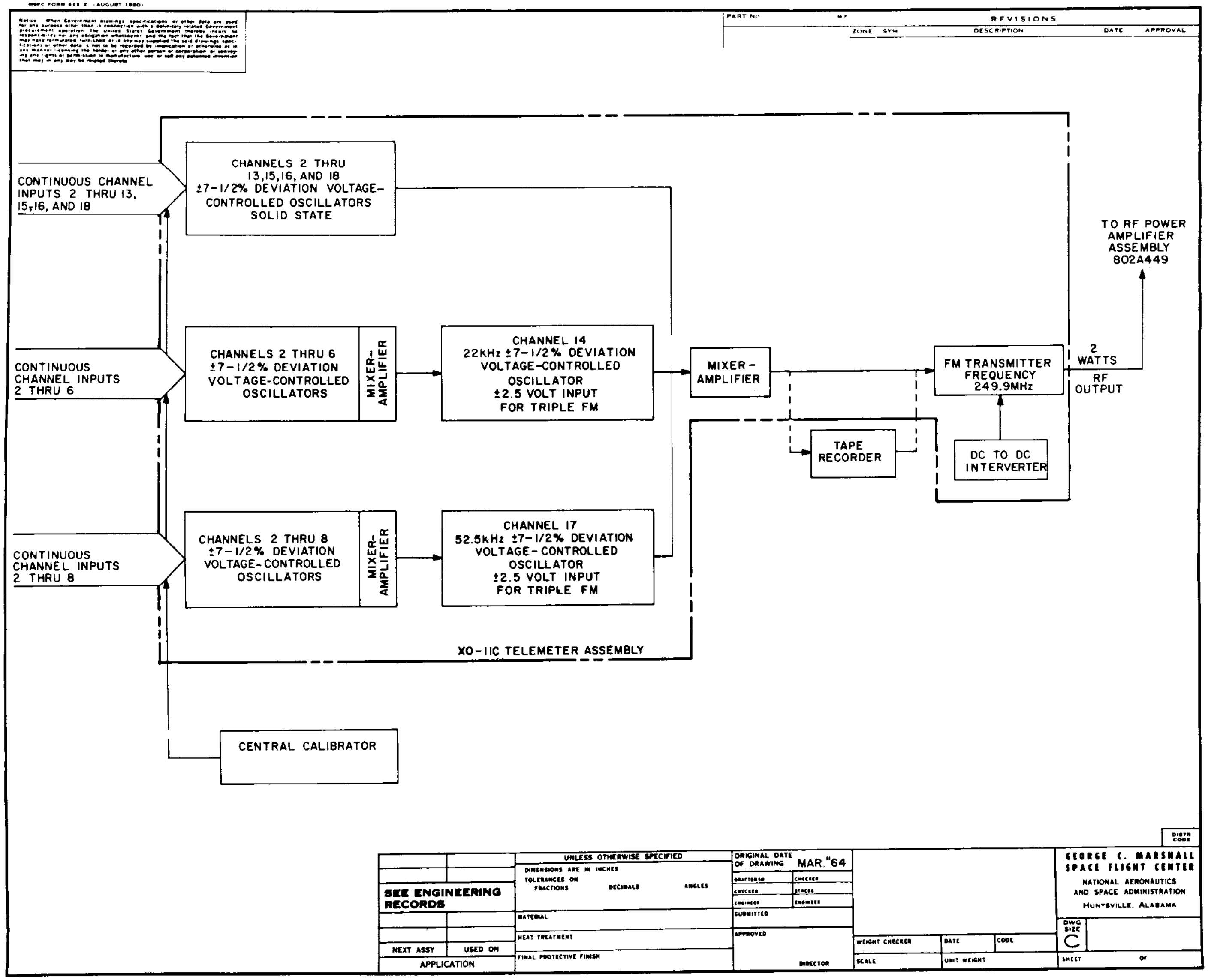


FIGURE 8. S-IU-6 TELEMETER LINK F5

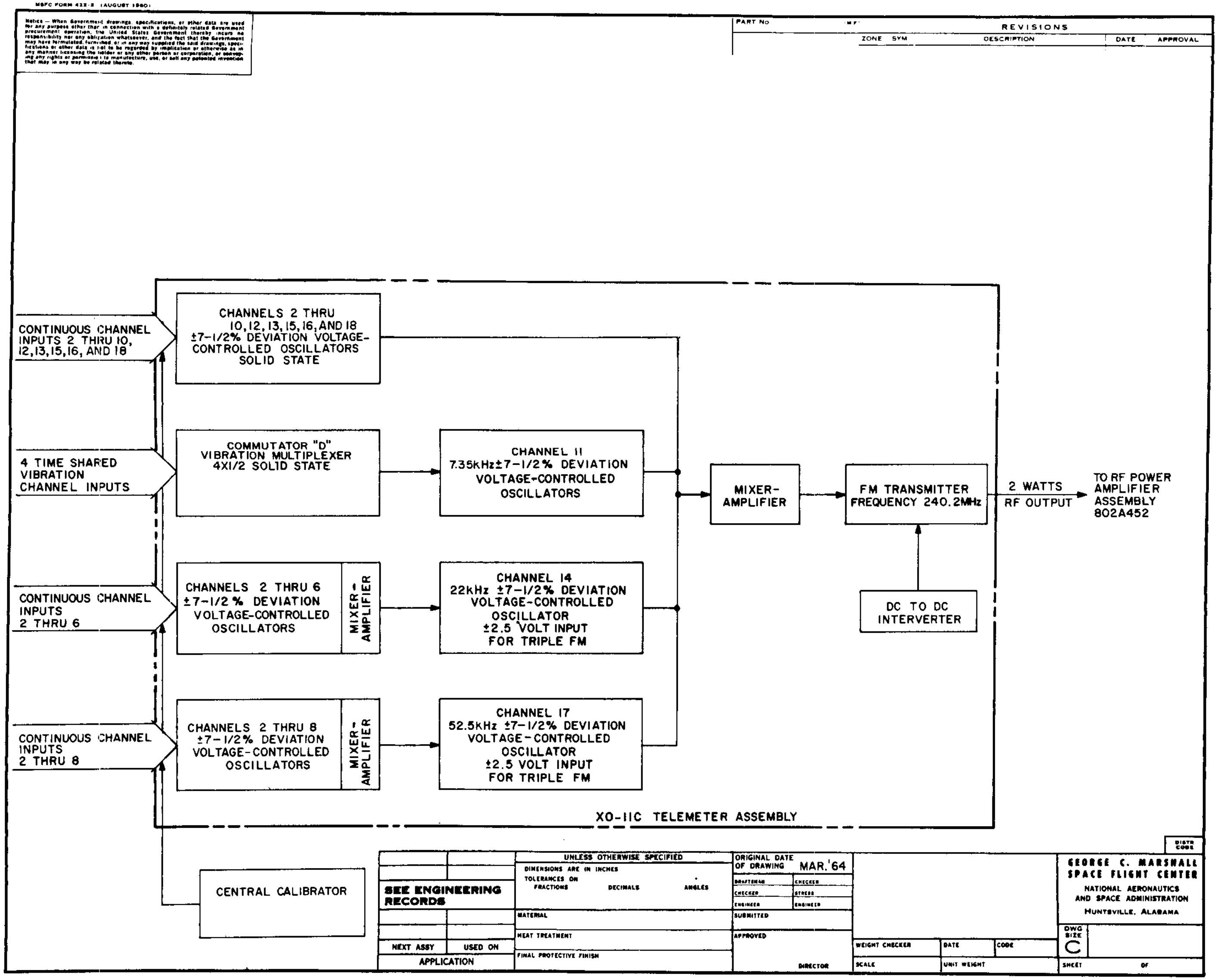


FIGURE 9. S-IU-6 TELEMETER LINK F6

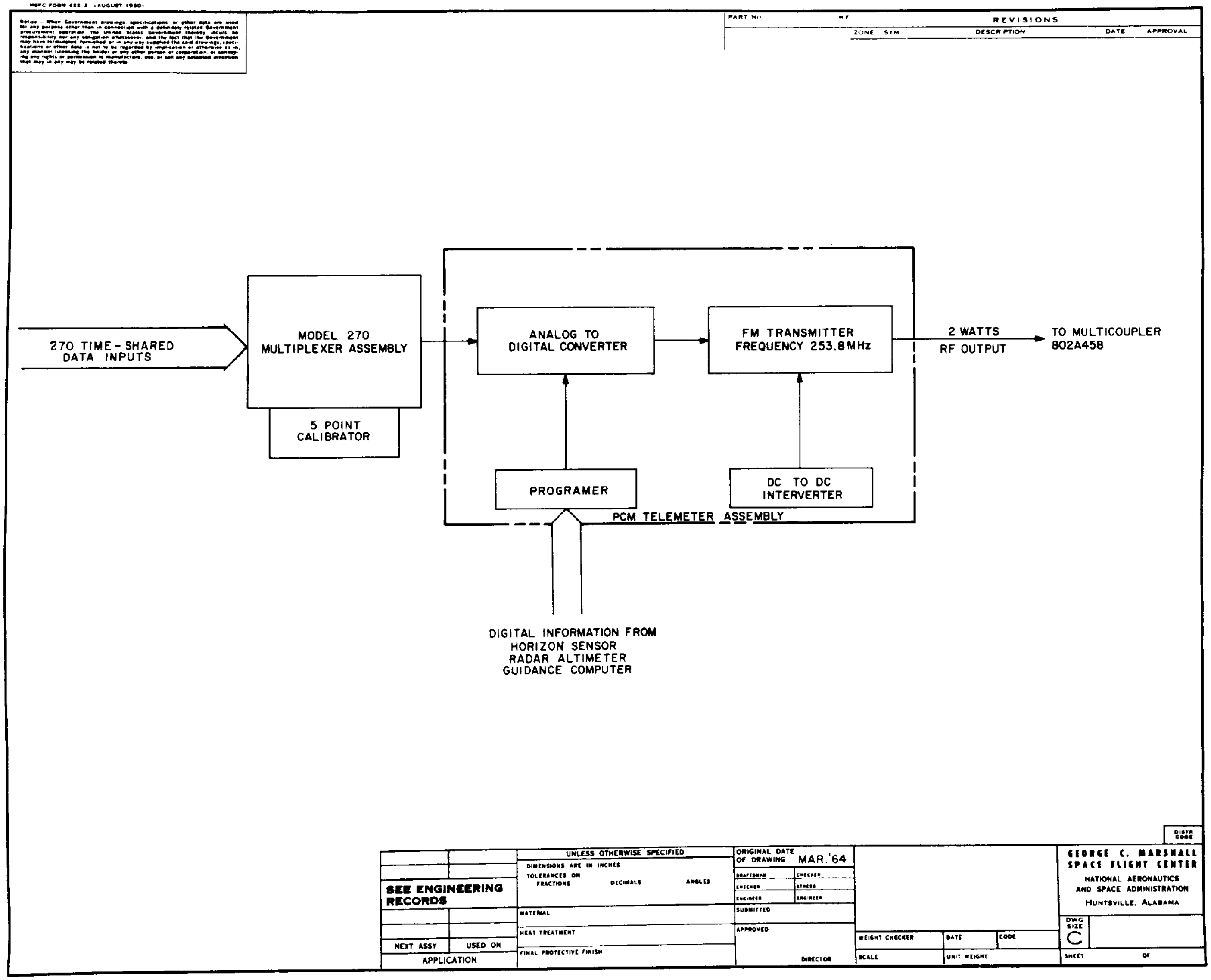


FIGURE 10. S-IU-6 TELEMETER LINK P1

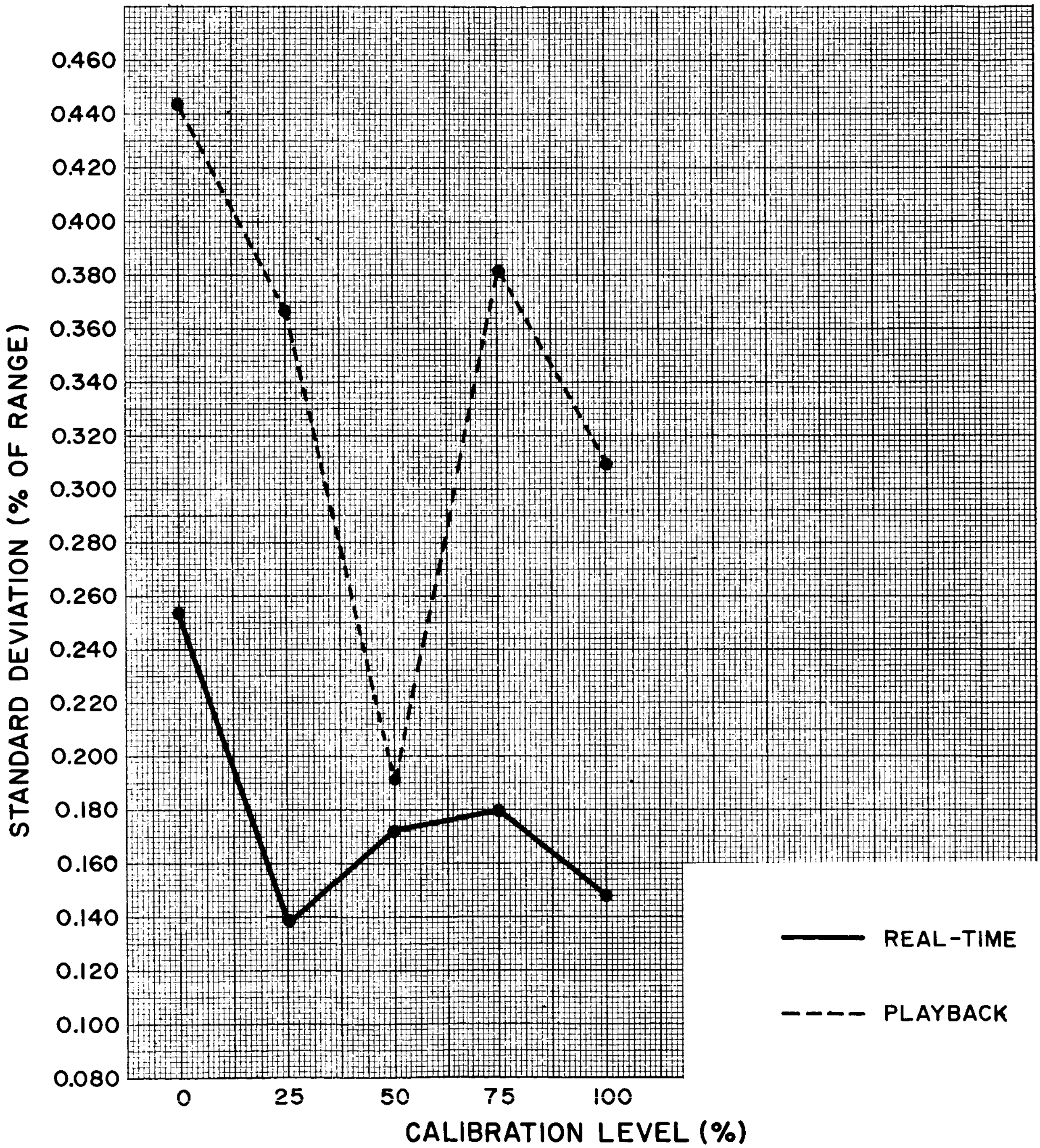


FIGURE 11. REAL-TIME VERSUS PLAYBACK DATA FOR SA-5, LINK F2, CHANNEL 5

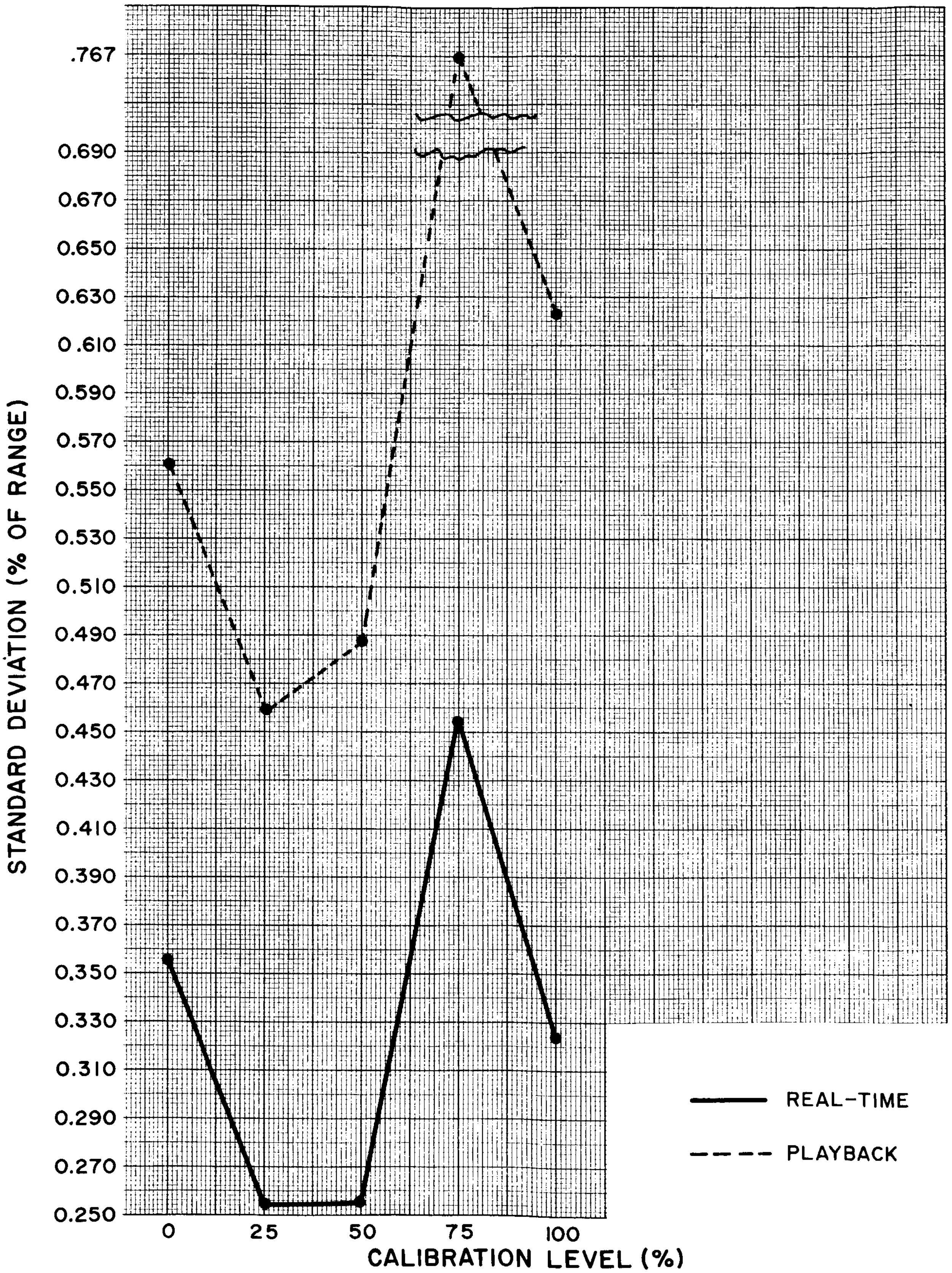


FIGURE 12. REAL-TIME VERSUS PLAYBACK DATA FOR SA-5, LINK F2, CHANNEL 10

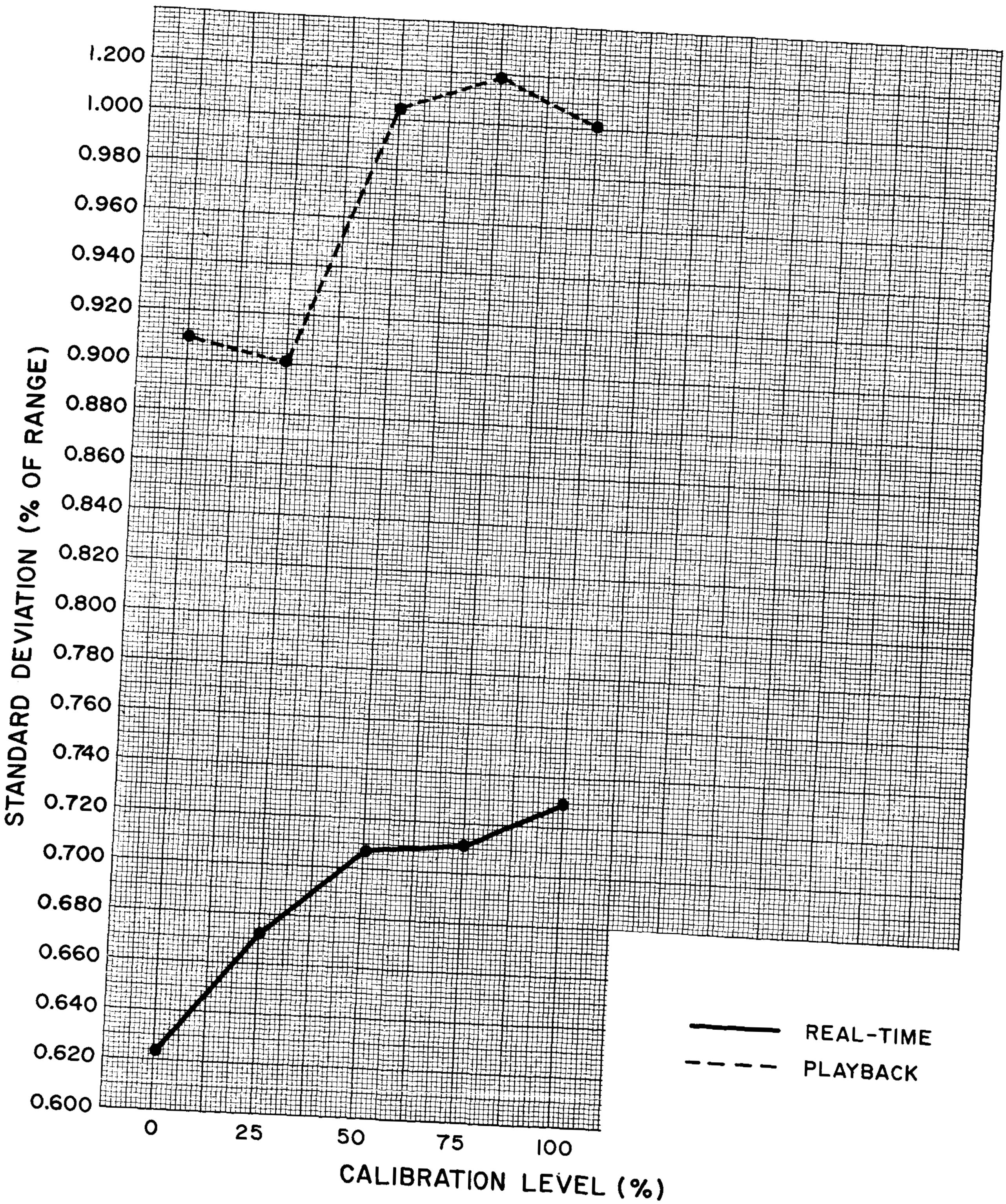


FIGURE 13. REAL-TIME VERSUS PLAYBACK DATA FOR SA-5, LINK F2, CHANNEL 14

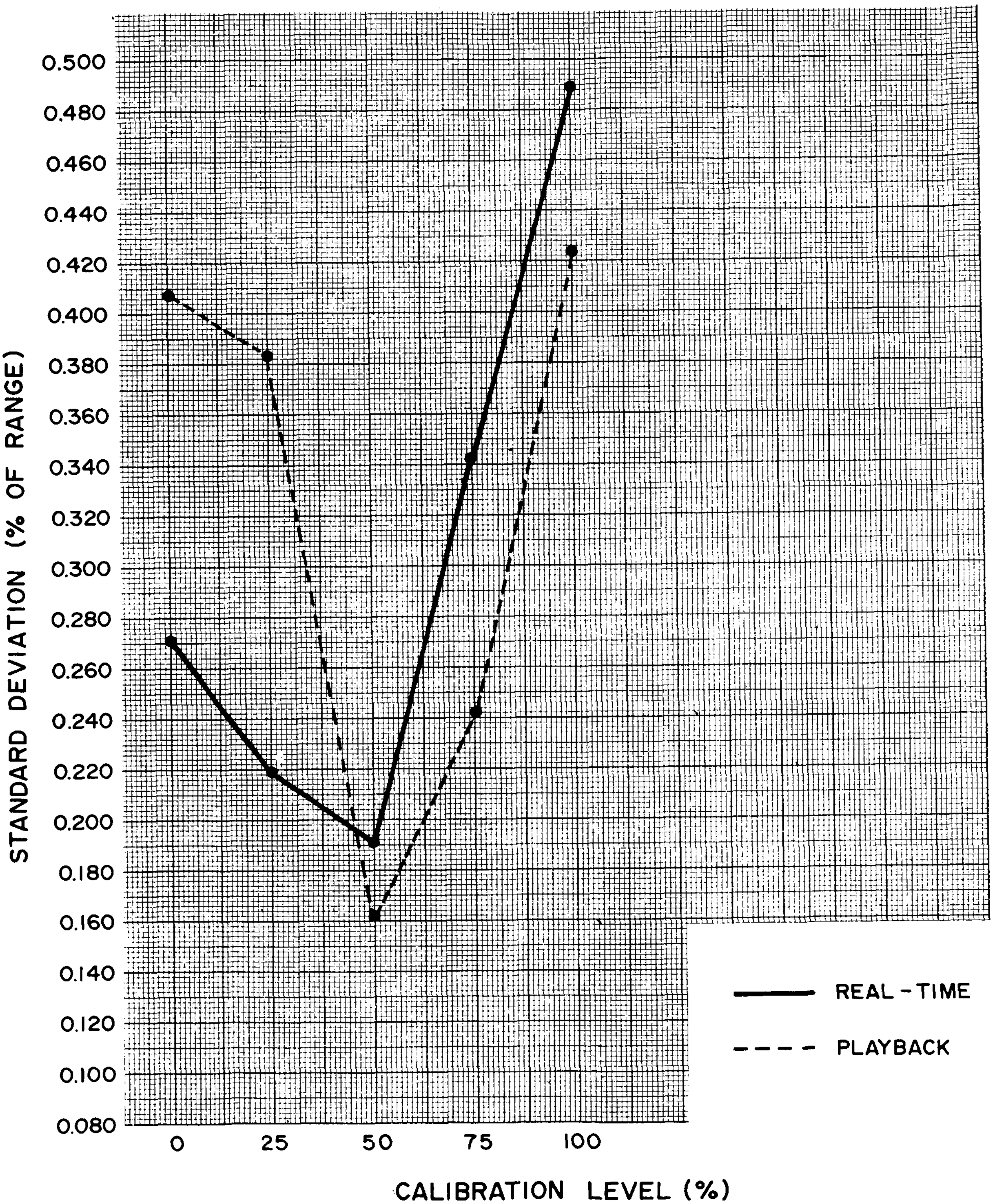


FIGURE 14. REAL-TIME VERSUS PLAYBACK DATA FOR SA-6, LINK F2, CHANNEL 5

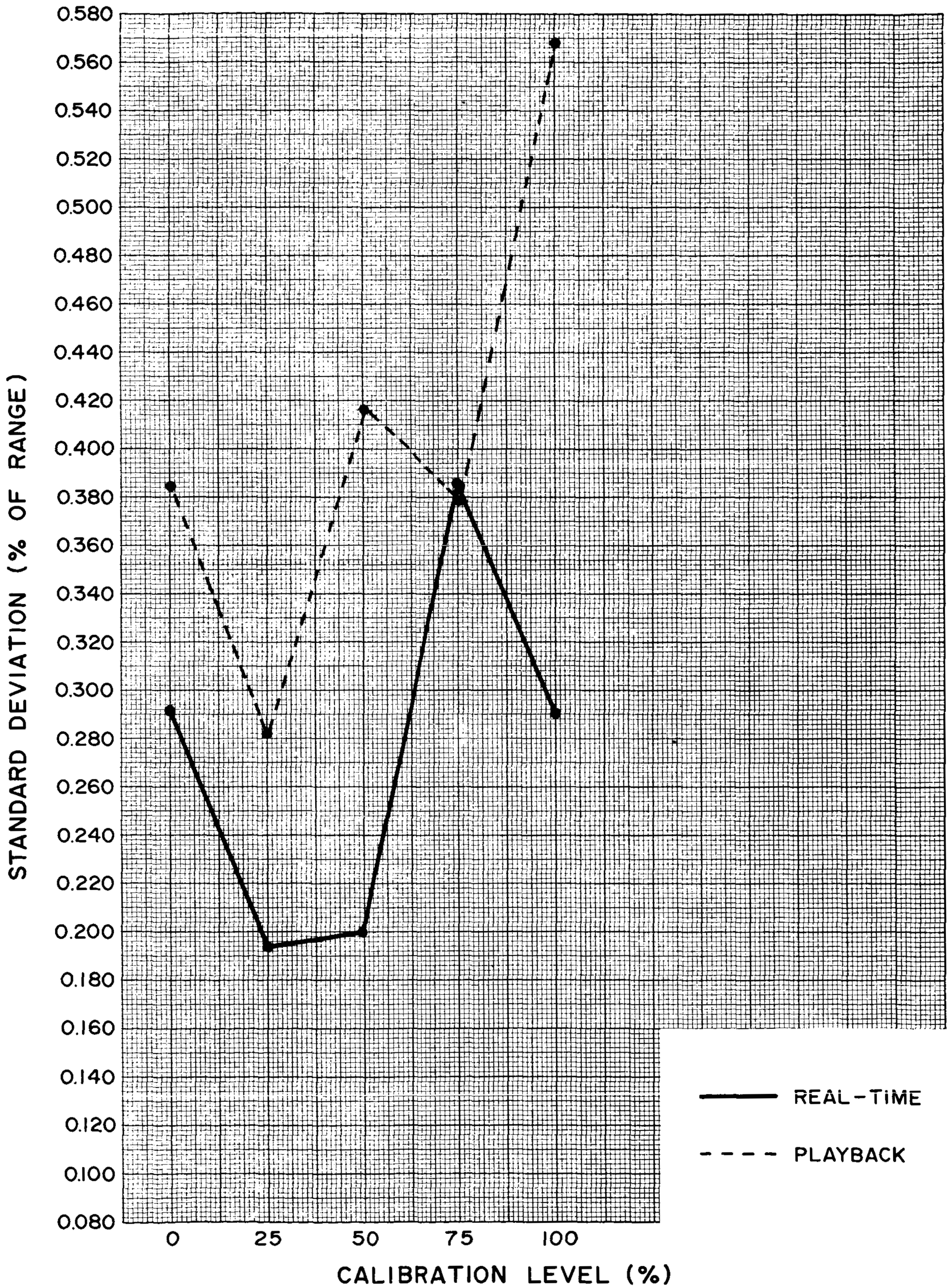


FIGURE 15. REAL-TIME VERSUS PLAYBACK DATA FOR SA-6, LINK F2, CHANNEL 10

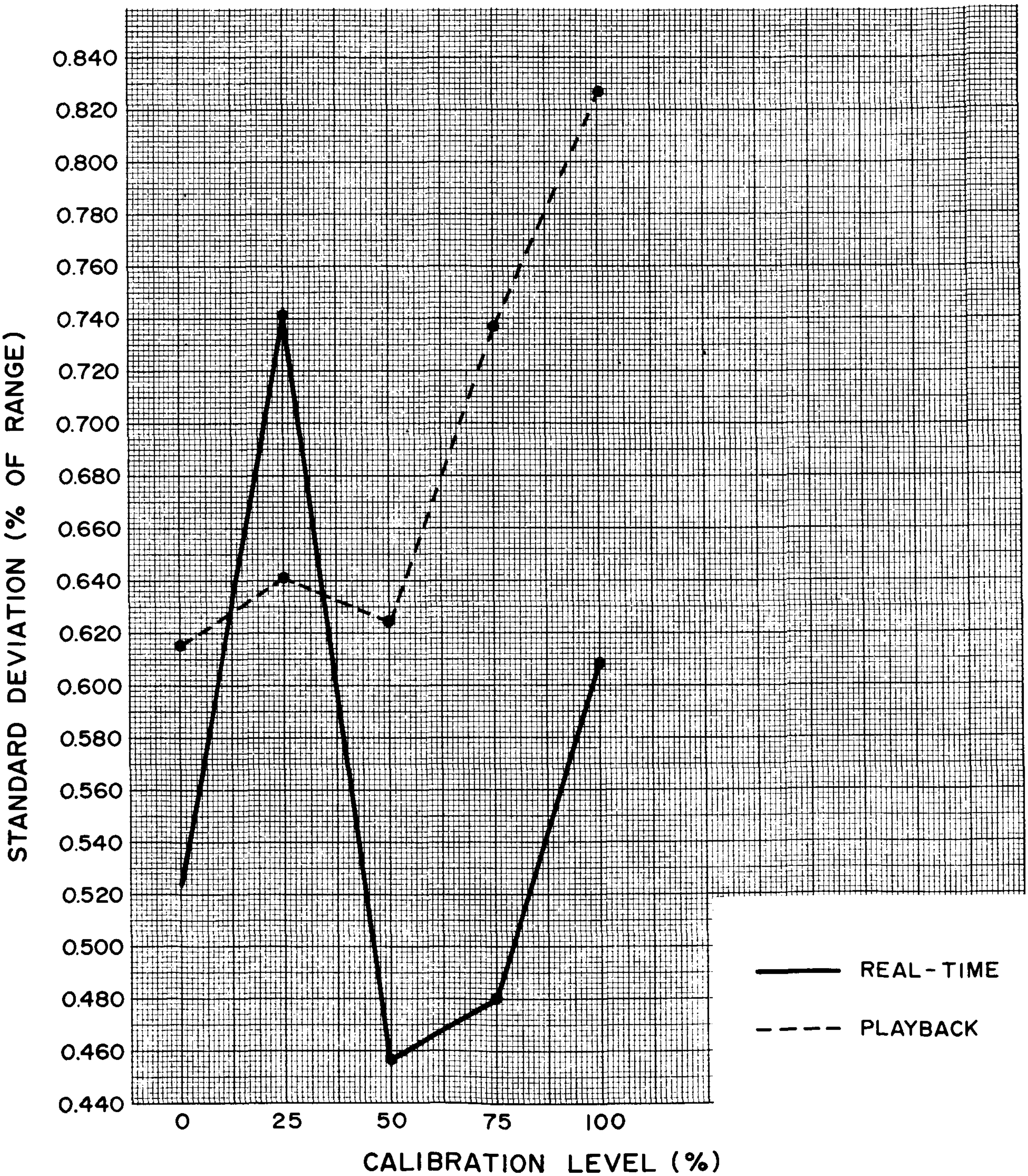


FIGURE 16. REAL-TIME VERSUS PLAYBACK DATA FOR SA-6, LINK F2, CHANNEL 14

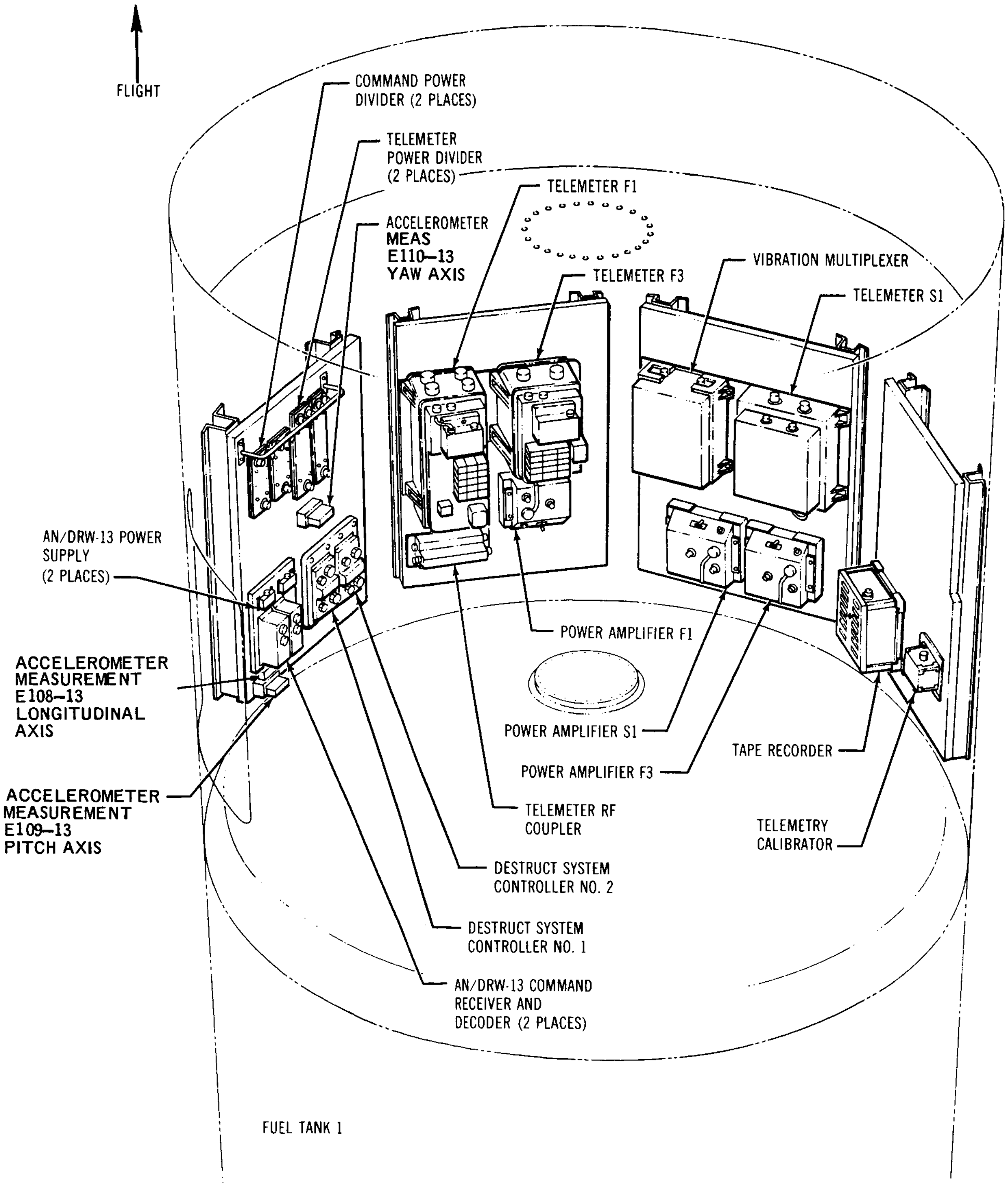


FIGURE 17. CANISTER F1, INSTRUMENT COMPARTMENT 13

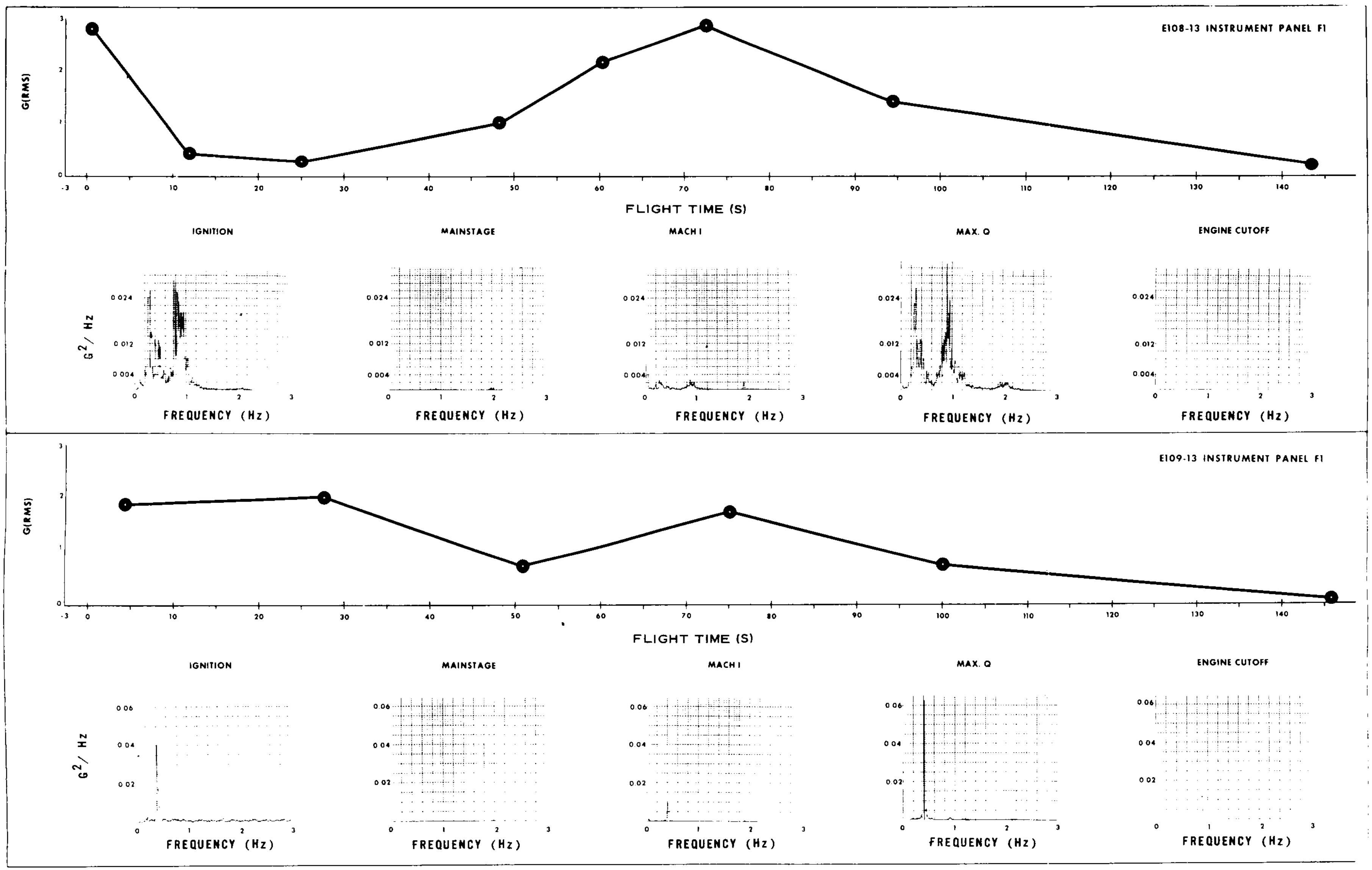


FIGURE 18. CANISTER F1, INSTRUMENT COMPARTMENT 13 VIBRATION DATA

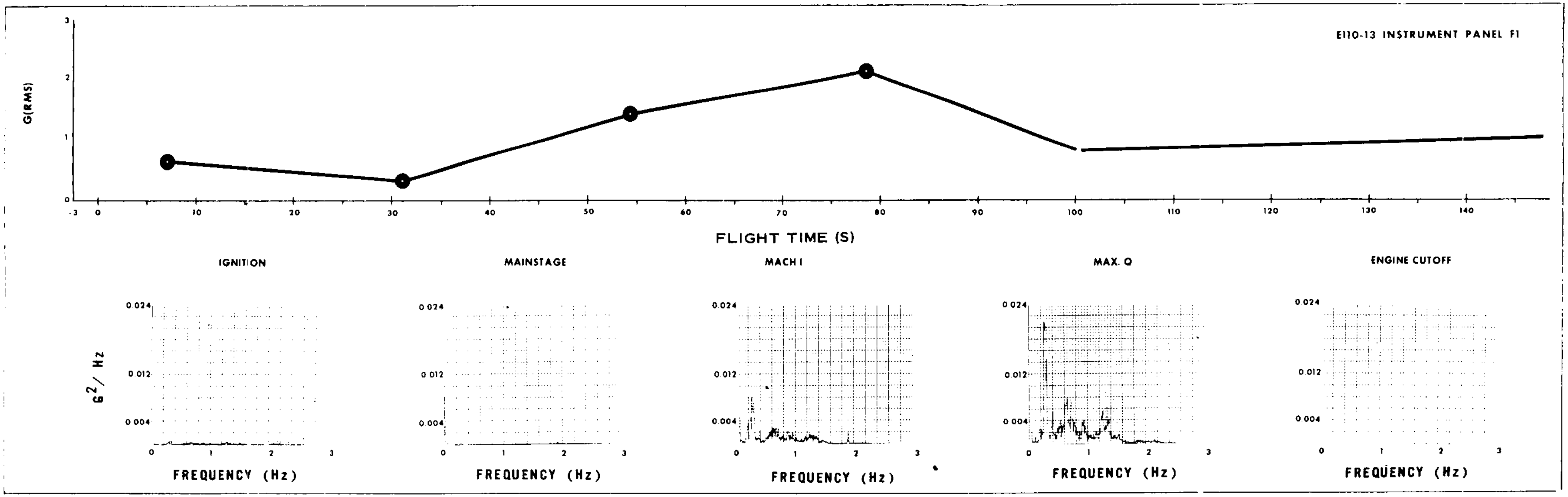


FIGURE 19. CANISTER F1, INSTRUMENT COMPARTMENT 13 VIBRATION DATA

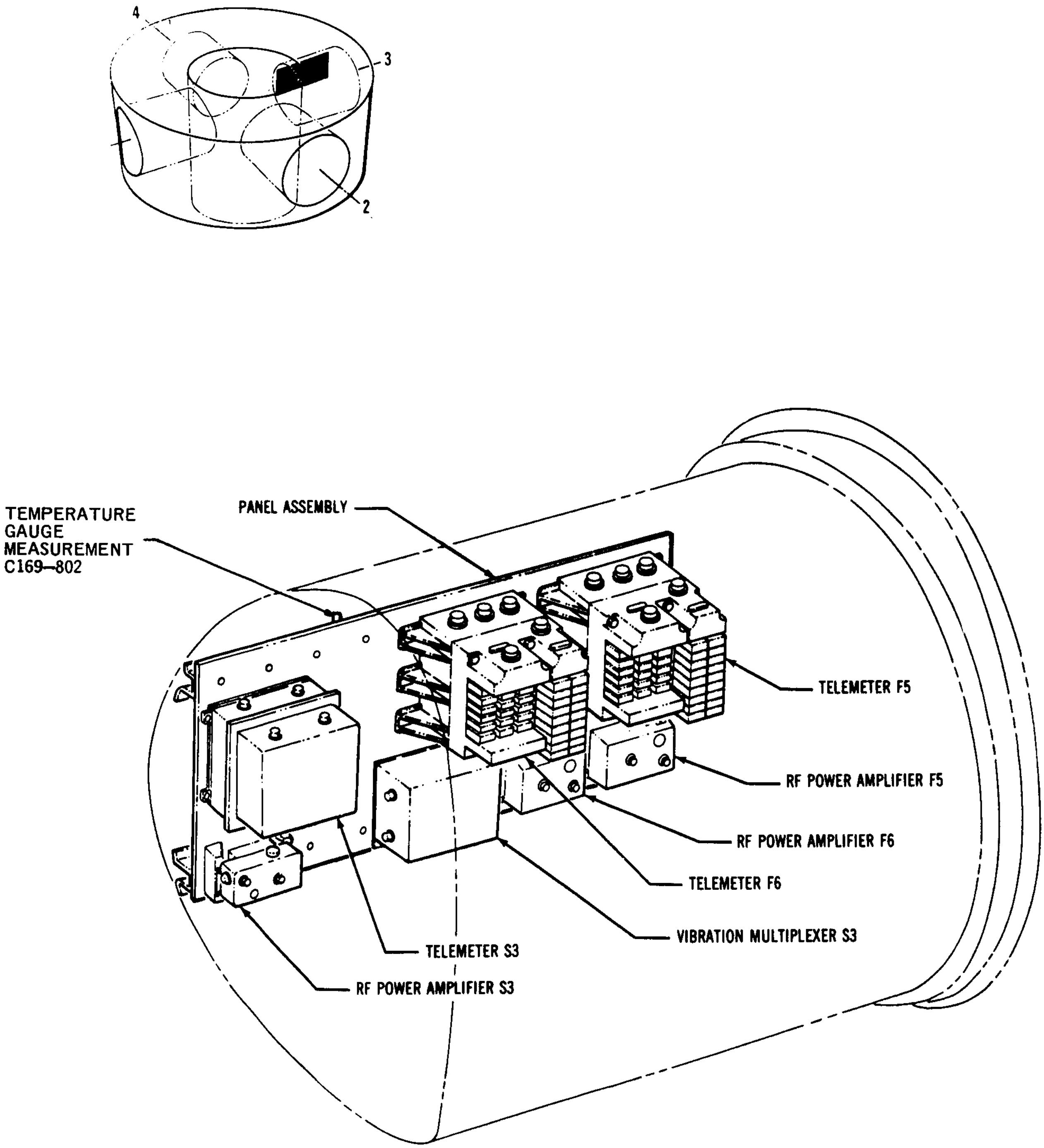


FIGURE 20. S-IU-6 INSTRUMENT UNIT, TUBE 3, RIGHT SIDE

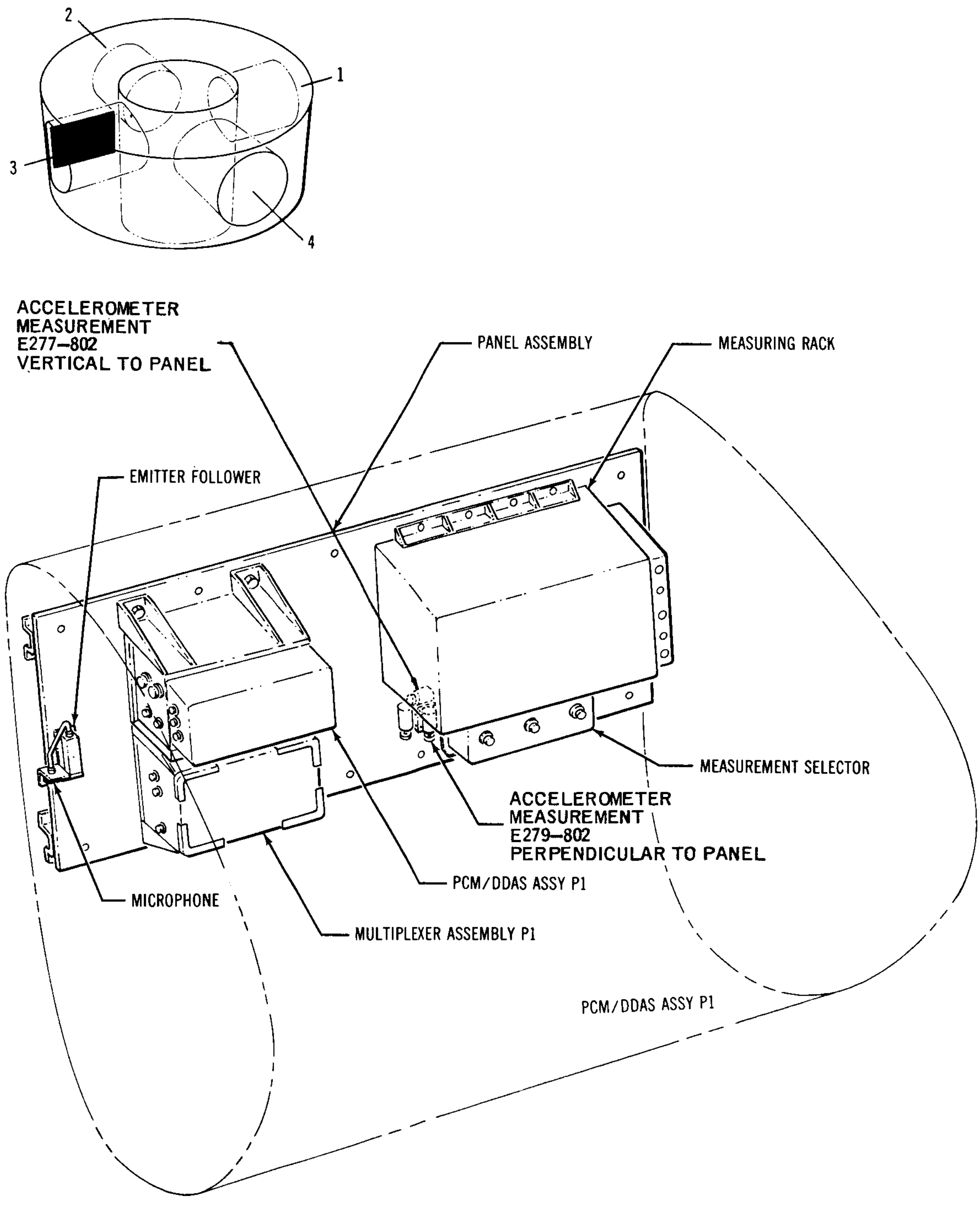


FIGURE 21. S-IU-6 INSTRUMENT UNIT, TUBE 3, LEFT SIDE

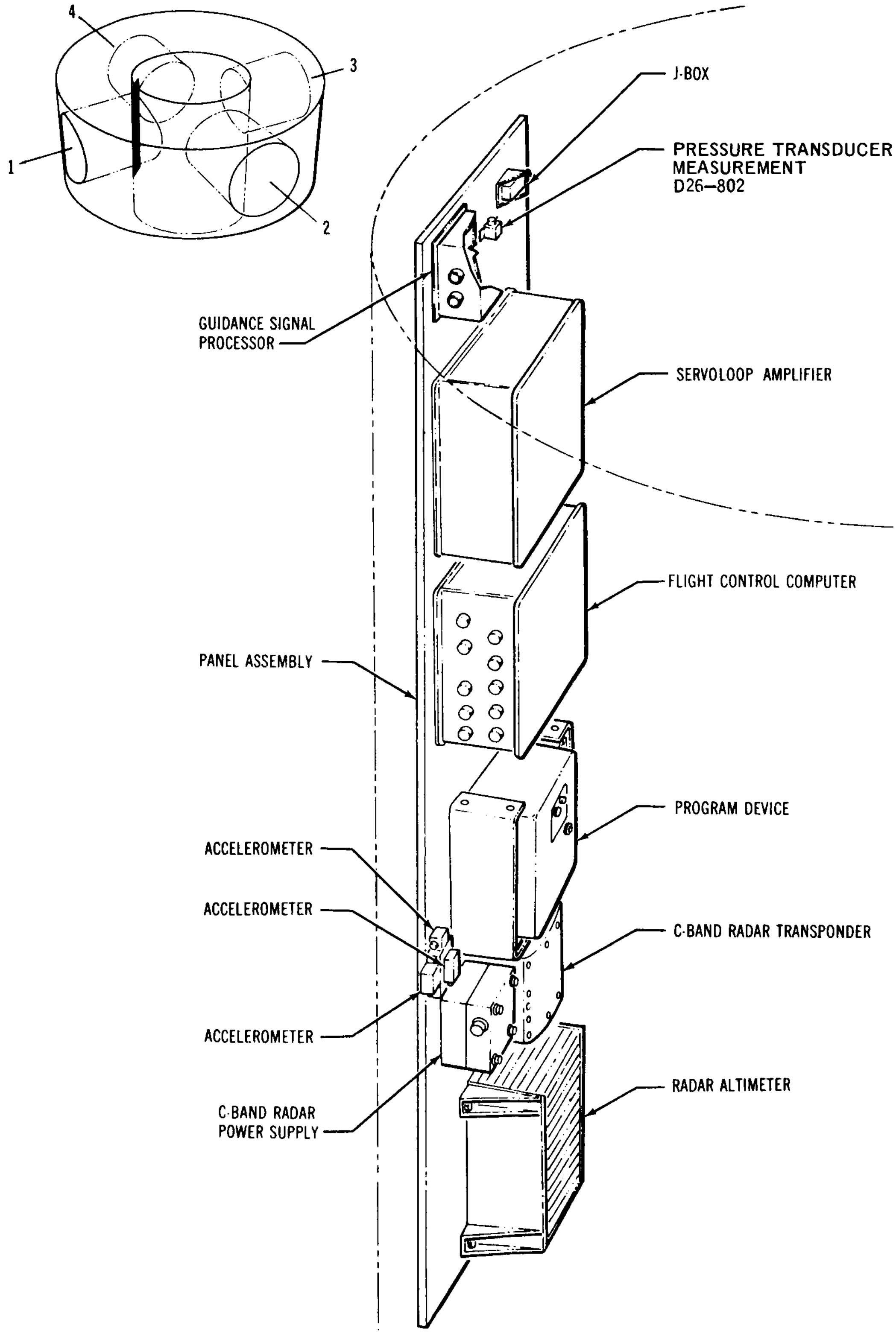


FIGURE 22. S-IU-6 INSTRUMENT UNIT, TUBE 5

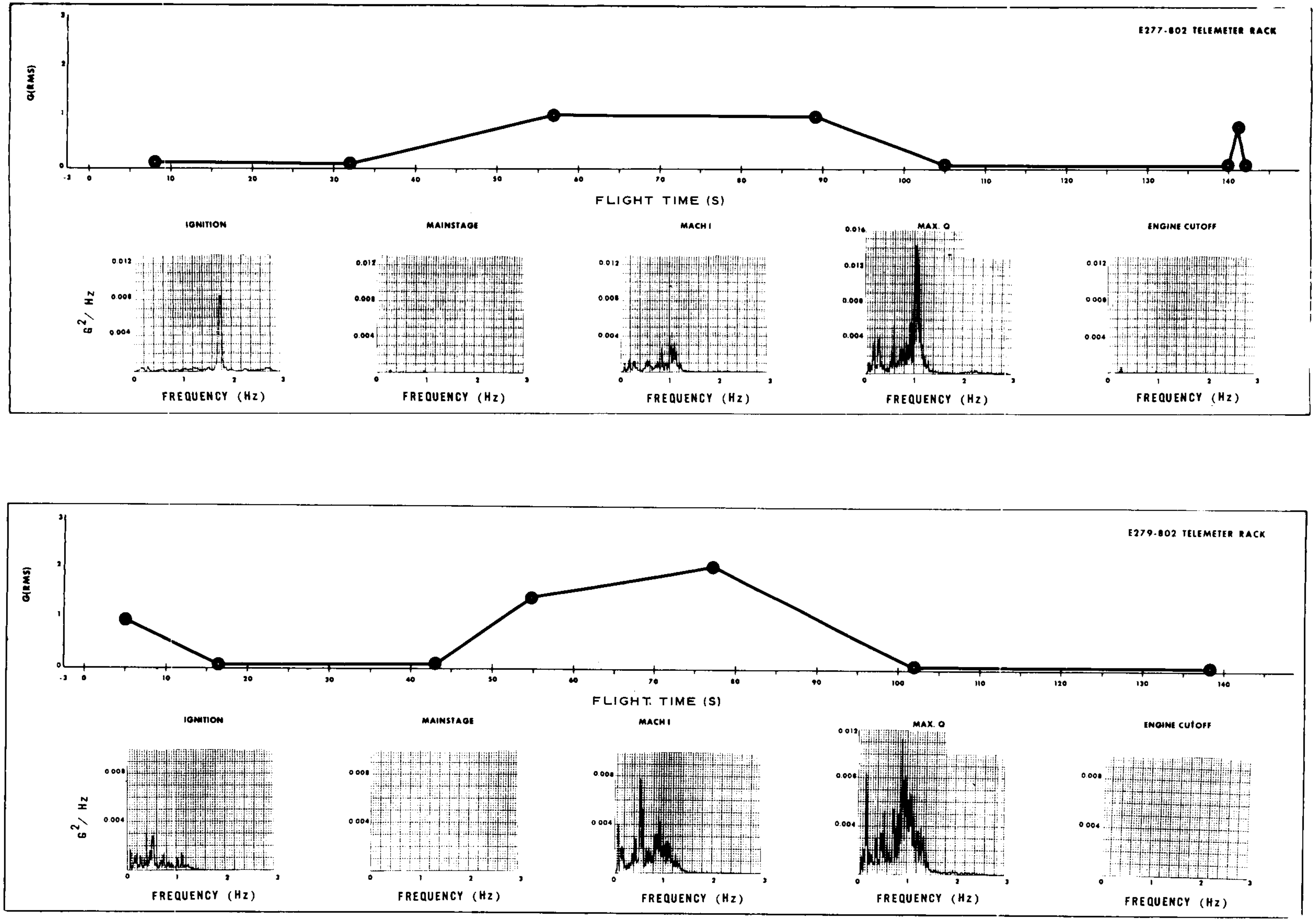


FIGURE 23. S-IU-6 INSTRUMENT UNIT VIBRATION DATA

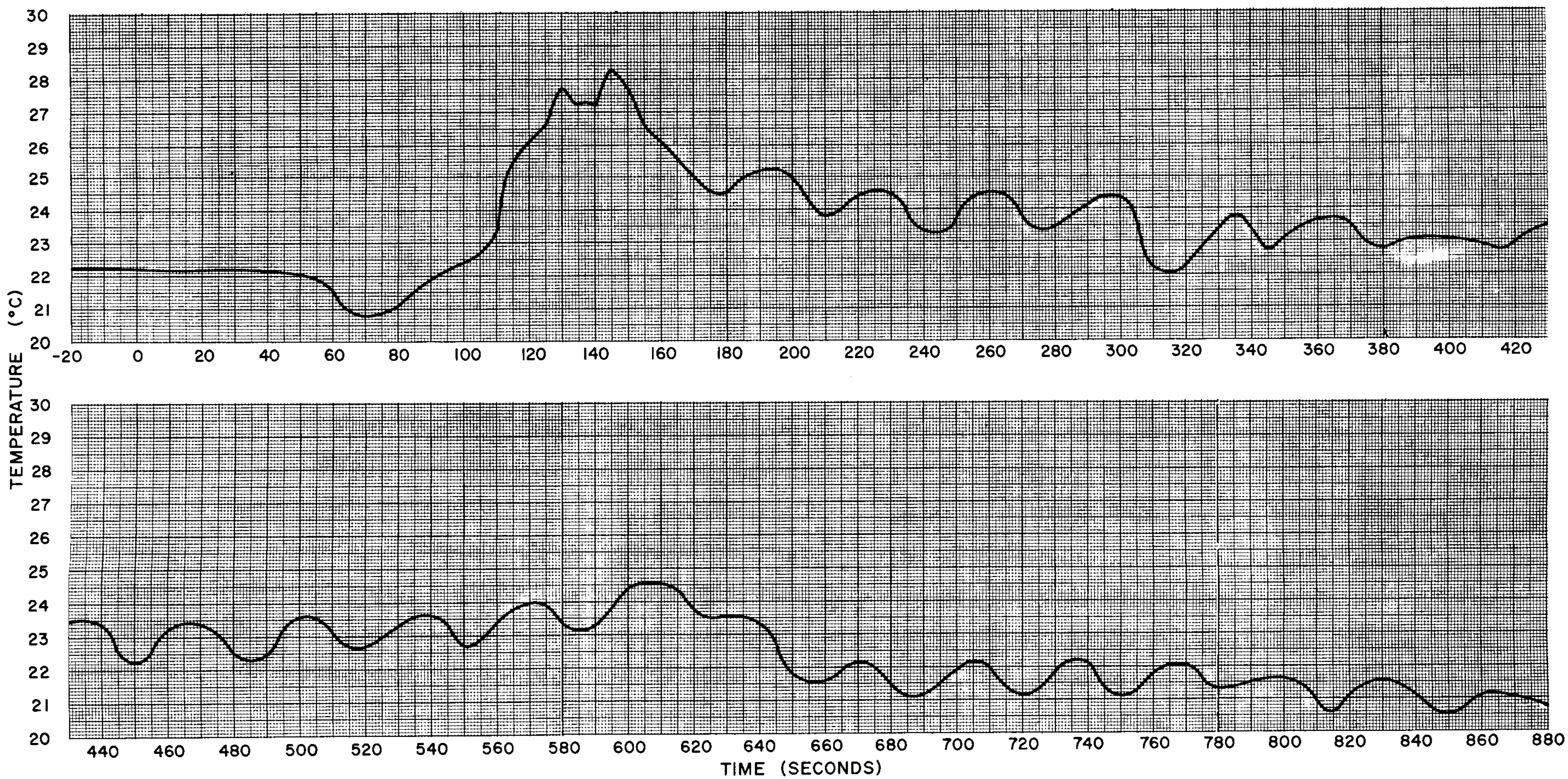


FIGURE 24. S-IU-6 INSTRUMENT UNIT TEMPERATURE DATA, 0 to 880 SECONDS OF FLIGHT TIME

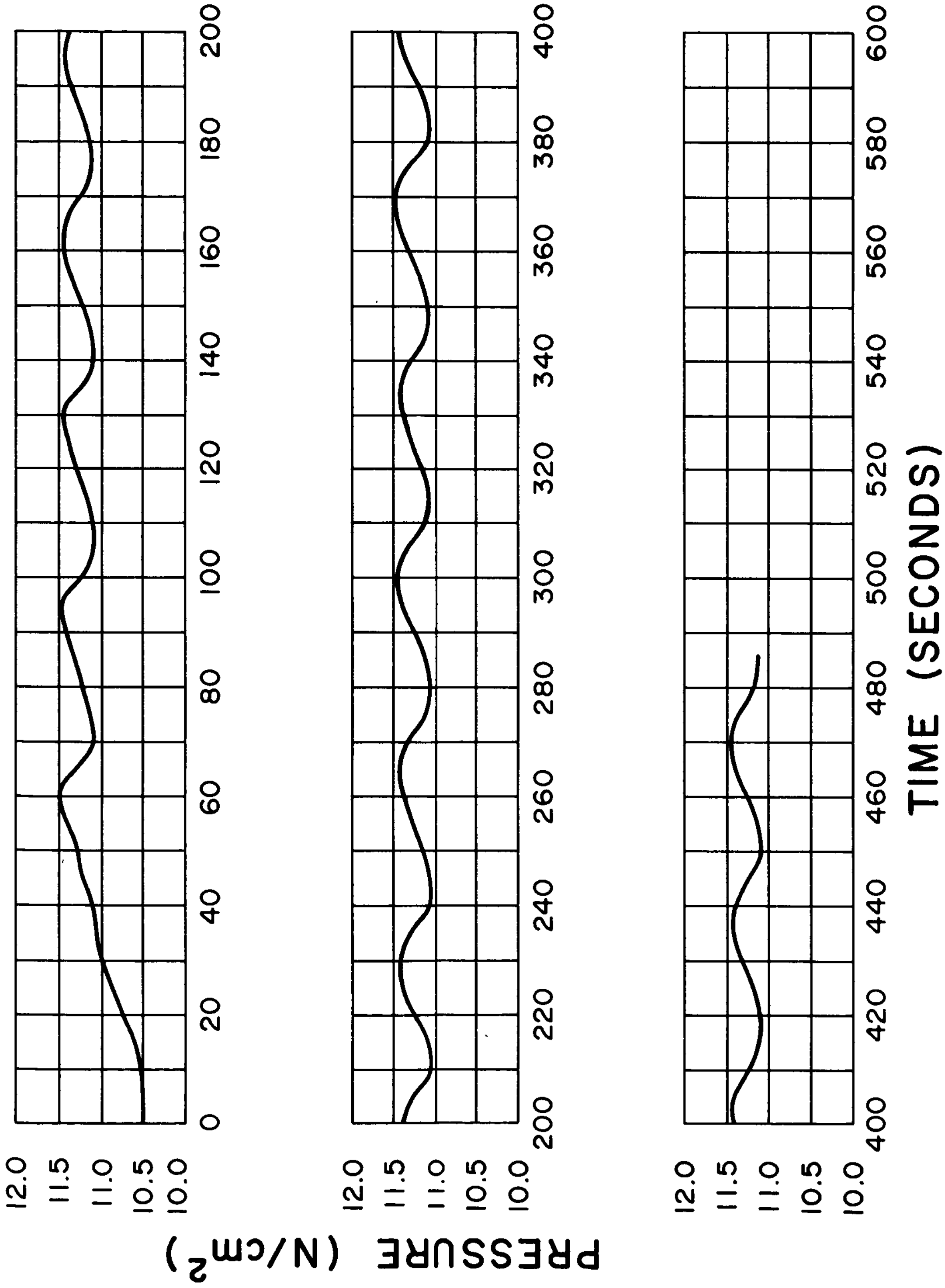


FIGURE 25. S-IU-6 INSTRUMENT UNIT, TUBE 3 PRESSURE DATA

APPENDIX

TABLE 1. SA-6 LINK F1 PREFLIGHT CALIBRATION DATA *

Channel No.	Calibration Levels										Total Dev
	0%		25%		50%		75%		100%		
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	
3	0	0. 185	25. 542	0. 429	50. 188	0. 343	75. 112	0. 173	100	0. 196	0. 284
4	0	0. 180	25. 286	0. 278	50. 293	0. 203	74. 923	0. 244	100	0. 169	0. 219
5	0	0. 334	25. 199	0. 252	50. 155	0. 280	74. 934	0. 228	100	0. 222	0. 266
6	0	0. 256	25. 210	0. 255	50. 143	0. 237	74. 812	0. 224	100	0. 219	0. 239
7	0	0. 275	25. 213	0. 311	50. 138	0. 277	74. 787	0. 457	100	0. 318	0. 334
8	0	0. 204	24. 894	0. 241	50. 067	0. 286	74. 950	0. 481	100	0. 397	0. 338
9	0	0. 215	24. 798	0. 384	49. 884	0. 434	74. 737	0. 304	100	0. 307	0. 337
13	0	0. 461	25. 137	0. 324	50. 217	0. 349	74. 585	0. 564	100	0. 307	0. 412
14	0	0. 323	24. 984	0. 289	49. 802	0. 756	74. 731	0. 546	100	0. 431	0. 498

* All figures shown in percent of range

TABLE 2. SA-6 LINK F2 PREFLIGHT CALIBRATION DATA *

Channel No.	Calibration Levels										Total Dev
	0%		25%		50%		75%		100%		
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	
2	0	0.236	25.294	0.265	49.860	0.205	74.829	0.652	100	0.555	0.425
3	0	0.432	25.417	0.553	50.226	0.753	74.892	0.299	100	0.227	0.490
4	0	0.399	25.246	0.443	50.213	0.597	75.078	0.343	100	0.295	0.428
5	0	0.386	24.812	0.272	49.192	0.296	73.867	0.315	100	0.581	0.387
10	0	0.318	25.484	0.242	50.194	0.222	74.726	0.355	100	0.272	0.286
13	0	0.208	25.826	0.420	50.466	0.315	75.239	0.363	100	0.467	0.366
14	0	0.269	25.101	0.338	50.104	0.511	75.271	0.619	100	0.329	0.433

* All figures shown in percent of range

TABLE 3. SA-6 LINK F3 PREFLIGHT CALIBRATION DATA *

Channel No.	Calibration Levels										Total Dev
	0%		25%		50%		75%		100%		
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	
2	0	0.208	25.544	0.129	49.978	0.191	75.028	0.244	100	0.198	0.197
3	0	0.203	25.193	0.291	50.219	0.259	75.345	0.165	100	0.218	0.232
4	0	0.242	25.461	0.223	50.241	0.167	75.091	0.158	100	0.209	0.202
5	0	0.178	25.458	0.262	50.283	0.195	75.229	0.283	100	0.295	0.247
10	0	0.277	25.889	0.238	50.514	0.316	75.396	0.210	100	0.236	0.258
13	0	0.350	25.467	0.272	50.402	0.337	75.868	0.519	100	0.303	0.367
14	0	0.300	25.158	0.424	50.388	0.436	74.973	0.626	100	0.287	0.432

* All figures shown in percent of range

TABLE 4. SA-6 LINK F4 PREFLIGHT CALIBRATION DATA *

Channel No.	Calibration Levels										Total Dev
	0%		25%		50%		75%		100%		
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	
2	0	0. 202	25. 342	0. 268	49. 984	0. 189	75. 008	0. 253	100	0. 200	0. 225
3	0	0. 316	25. 336	0. 238	50. 099	0. 529	74. 962	0. 244	100	0. 214	0. 329
4	0	0. 247	25. 688	0. 355	50. 136	0. 172	75. 215	0. 188	100	0. 192	0. 241
5	0	0. 215	25. 187	0. 226	50. 088	0. 206	75. 088	0. 260	100	0. 238	0. 230
10	0	0. 249	25. 757	0. 215	49. 956	0. 255	75. 160	0. 228	100	0. 316	0. 255
13	0	0. 360	25. 386	0. 208	50. 098	0. 368	75. 256	0. 374	100	0. 477	0. 367
14	0	0. 441	25. 621	0. 352	50. 179	0. 359	75. 138	0. 344	100	0. 528	0. 411

* All figures shown in percent of range

TABLE 5. SA-6 LINK F5 PREFLIGHT CALIBRATION DATA *

Channel No.	Calibration Levels										Total Dev
	0%		25%		50%		75%		100%		
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	
2	0	0.297	25.061	0.246	50.077	0.380	74.829	0.388	100	0.258	0.346
3	0	0.679	25.356	1.333	50.072	0.520	75.074	0.323	100	0.289	0.734
4	0	0.272	25.303	0.172	49.983	0.165	74.915	0.155	100	0.278	0.216
5	0	0.248	25.315	0.172	50.022	0.178	74.859	0.199	100	0.174	0.196
7	0	0.197	24.928	0.196	49.912	0.299	74.972	0.265	100	0.298	0.255
9	0	0.409	24.731	0.247	49.995	0.342	74.747	0.397	100	0.395	0.363
11	0	0.264	25.052	0.497	50.049	0.444	75.155	0.503	100	0.379	0.427
12	0	0.369	25.252	0.301	50.493	0.514	75.361	0.357	100	0.463	0.408
15	0	0.596	25.528	0.433	50.159	0.343	75.151	0.439	100	0.490	0.468

* All figures shown in percent of range

TABLE 6. SA-6 LINK F6 PREFLIGHT CALIBRATION DATA *

Channel No.	Calibration Levels										Total Dev
	0%		25%		50%		75%		100%		
	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	Mean	Std Dev	
2	0	0. 229	24. 855	0. 212	49. 570	0. 160	74. 575	0. 228	100	0. 186	0. 205
3	0	0. 288	24. 793	0. 156	49. 995	0. 170	74. 906	0. 208	100	0. 145	0. 200
5	0	0. 193	25. 118	0. 232	49. 874	0. 177	74. 948	0. 158	100	0. 153	0. 185
6	0	0. 234	24. 771	0. 255	49. 639	0. 260	74. 550	0. 292	100	0. 283	0. 266
7	0	0. 234	25. 174	0. 172	49. 826	0. 210	74. 978	0. 252	100	0. 270	0. 230
9	0	0. 348	24. 728	0. 270	49. 541	0. 326	74. 571	0. 367	100	0. 246	0. 315
10	0	0. 286	25. 271	0. 265	49. 967	0. 205	74. 906	0. 326	100	0. 262	0. 272
12	0	0. 376	24. 986	0. 307	49. 800	0. 632	74. 667	0. 306	100	0. 365	0. 415

* All figures shown in percent of range

TABLE 7. SUMMARY OF SA-5 F-RATIO TESTS

Channel	Level (%)	F-Ratio *
5	0	3.078
	25	7.105
	50	1.233
	75	4.562
	100	4.318
10	0	2.500
	25	3.333
	50	3.703
	75	2.854
	100	3.740
14	0	2.134
	25	1.796
	50	2.125
	75	2.816
	100	2.350

* Sample Size:

$N_1 = 128$

$N_2 = 128$

Theoretical F Values:

$F_{0.01} = 0.621$

$F_{0.99} = 1.61$

TABLE 8. SUMMARY OF SA-6 F-RATIO TESTS

Channel	Level (%)	F-Ratio*
5	0	2.243
	25	3.062
	50	1.384
	75	2.000
	100	1.333
10	0	2.500
	25	2.078
	50	4.350
	75	1.027
	100	3.788
14	0	1.378
	25	1.228
	50	1.870
	75	2.365
	100	1.854

* Sample size

$N_1 = 128$
$N_2 = 128$

Theoretical F Values

$F_{0.01} = 0.621$

$F_{0.99} = 1.61$

TABLE 9. PAIRED DIFFERENCES OF REAL-TIME DATA VERSUS PLAYBACK DATA FOR PERCENT LEVEL

Channel	Unbiased Play-back Noise	Unbiased Real-Time Noise	Difference	Percent Increase
SA-5 Link F2	(0%)			
5	0.444	0.254	0.190	74.80
10	0.561	0.356	0.205	57.58
14	0.909	0.622	0.287	46.14
SA-6 Link F2	(0%)			
5	0.408	0.271	0.137	50.55
10	0.385	0.291	0.094	32.30
14	0.616	0.524	0.092	17.55
SA-5 Link F2	(25%)			
5	0.367	0.138	0.229	165.94
10	0.459	0.252	0.207	82.14
14	0.901	0.672	0.229	34.07
SA-6 Link F2	(25%)			
5	0.384	0.219	0.165	75.34
10	0.282	0.194	0.088	45.36
14	0.642	0.741	-0.99	-13.36
SA-5 Link F2	(50%)			
5	0.191	0.172	0.027	15.69
10	0.487	0.253	0.234	92.49
14	1.033	0.708	0.325	45.90
SA-6 Link F2	(50%)			
5	0.162	0.191	-0.029	-15.18
10	0.417	0.200	0.217	108.50
14	0.624	0.456	0.168	36.84
SA-5 Link F2	(75%)			
5	0.382	0.179	0.203	113.40
10	0.767	0.454	0.313	68.94
14	1.193	0.711	0.482	67.79

Table 9 (continued)

Channel	Unbiased Play-back Noise	Unbiased Real-Time Noise	Difference	Percent Increase
SA-6 Link F2	(75%)			
5	0. 243	0. 343	-0. 100	-29. 15
10	0. 379	0. 385	-0. 006	- 0. 155
14	0. 737	0. 480	0. 257	53. 54
SA-5 Link F2	(100%)			
5	0. 309	0. 147	0. 162	110. 20
10	0. 623	0. 323	0. 300	92. 87
14	1. 119	0. 730	0. 389	53. 28
SA-6 Link F2	(100%)			
5	0. 424	0. 489	-0. 065	-13. 29
10	0. 568	0. 291	0. 277	95. 18
14	0. 828	0. 608	0. 220	36. 18
		Total	5. 198	1,601. 435

TABLE 10. PAIRED DIFFERENCES OF REAL-TIME CALIBRATION LEVEL MEANS IN RAW COUNTS VERSUS AIRBORNE PLAYBACK CALIBRATION MEANS IN RAW COUNTS

Channel	Playback Mean	Real-Time Mean	Real-Time Range	Difference in Counts	Percent Decrease
SA-5 link F2	(0%)				
5	49.820	46.571	924.523	-3.249	-0.351
10	70.687	71.562	903.320	0.875	0.097
14	61.148	67.313	891.977	6.165	0.691
SA-6 link F2	(0%)				
5	83.844	83.086	898.585	-0.758	-0.084
10	67.625	76.297	898.437	8.672	0.965
14	55.437	61.061	893.556	5.624	0.629
SA-5 link F2	(25%)				
5	283.274	282.914	924.523	-0.360	-0.039
10	299.382	303.007	903.320	3.625	0.401
14	289.735	295.140	891.977	5.405	0.106
SA-6 link F2	(25%)				
5	307.094	312.359	898.585	5.265	0.586
10	294.281	306.070	898.437	11.789	1.312
14	280.243	289.312	893.556	9.069	1.015
SA-5 link F2	(50%)				
5	513.047	512.429	924.523	-0.618	-0.067
10	526.570	527.399	903.320	0.829	0.092
14	512.132	517.415	891.977	5.283	0.592
SA-6 link F2	(50%)				
5	532.235	535.445	898.585	3.210	0.357
10	520.570	530.148	898.437	9.578	1.066
14	504.882	511.507	893.556	6.625	0.741

TABLE 10. (continued)

Channel	Playback Mean	Real-Time Mean	Real-Time Range	Difference in Counts	Percent Decrease
SA-5 link F)	(75%)				
5	741. 187	741. 165	924. 523	-0. 022	-0. 002
10	751. 196	750. 406	903. 320	-0. 790	-0. 087
14	734. 461	738. 447	891. 977	3. 986	0. 447
SA-6 link F2	(75%)				
5	757. 290	758. 766	898. 585	1. 476	0. 164
10	746. 304	752. 266	898. 437	5. 962	0. 664
14	728. 609	732. 891	893. 556	4. 282	0. 479
SA-5 link F2	(100%)				
5	970. 695	971. 094	924. 523	0. 399	0. 043
10	979. 000	974. 882	903. 320	-4. 118	-0. 456
14	955. 461	959. 290	891. 977	3. 829	0. 429
SA-6 link F2	(100%)				
5	984. 757	981. 671	898. 585	-3. 086	-0. 343
10	976. 868	974. 734	898. 437	-2. 134	-0. 237
14	953. 539	954. 617	893. 556	1. 078	0. 121

REFERENCE

1. Duncan, Acheson J., Quality Control and Industrial Statistics, Richard D. Irwin, Inc., Homewood, Illinois, 1959.

APPROVAL TM X-53284

SPACE VEHICLE SA-6 TELEMETRY SYSTEM

By

Telemetry Performance Evaluation Office, R-ASTR-ITP

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

This report has also been reviewed and approved for technical accuracy.

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